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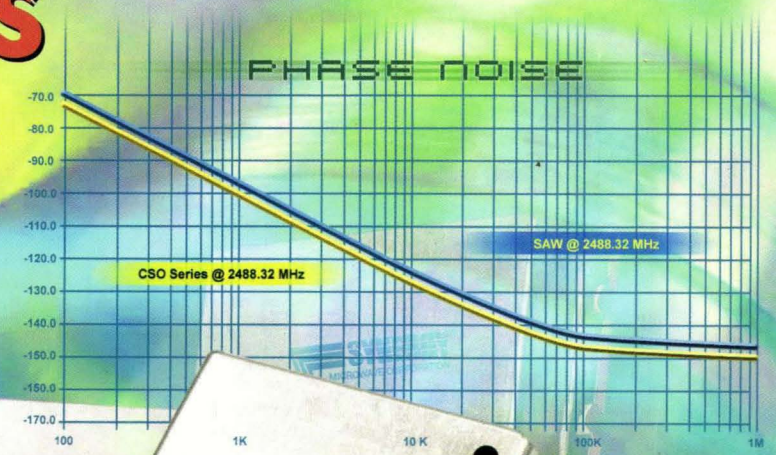
Microwaves & RF

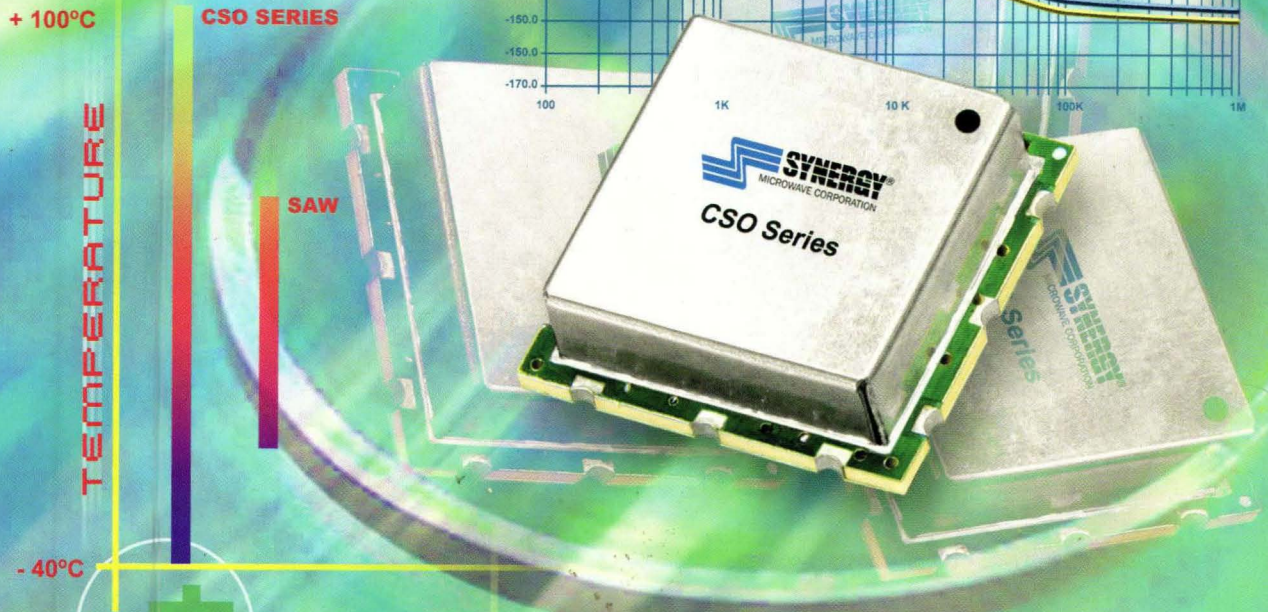
News
Sizing up the Third Annual MES

Design Feature
Reviewing SDARS antenna requirements

Product Technology
Low-cost transceiver drives wireless USB

Ceramic Resonator Oscillators Challenge SAWs



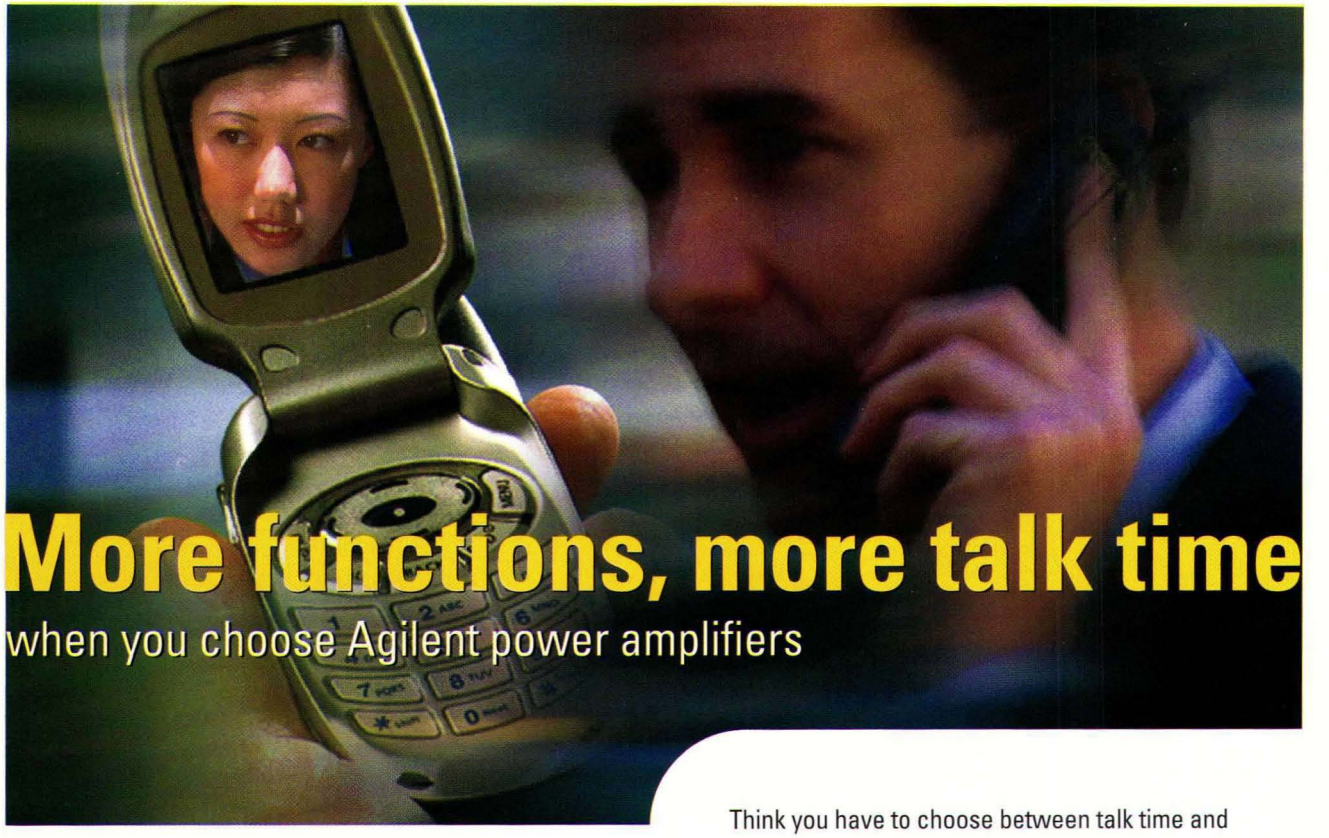


CSO SERIES

622.08 SAW 2488.32

QUENCY

Military Electronics Issue



More functions, more talk time

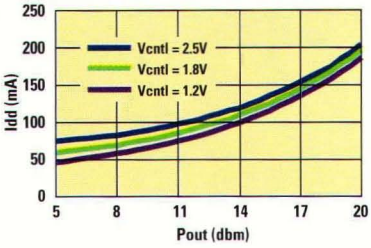
when you choose Agilent power amplifiers

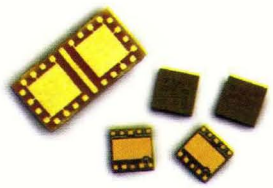
CDMA PAs: Efficiency at Low Vdd

	PAE (%)			
Vdd1 & Vdd2 (V)	3.4	2.0	1.0	Freq (MHz)
ACPM-7833	6.2	10.2	18.2	1880
ACPM-7813	6.1	10.1	18.6	836

Test conditions: Pout = 14dBm Vbias = 3.4V

ACPM-7833: Idd vs Pout





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Description	Model Number	Frequency
Card Cage	OCC-1	-
Power Supply	PS-OCC-1	-
L-Band Receiver	OCCR-103000-1	10–3000 MHz
L-Band Transmitter	OCCT-103000-1	10–3000 MHz
C-Band Receiver	OCCR-3442-1	3.4–4.2 GHz
Broadband Receiver	OCCR-95012750-1	0.95–12.75 GHz

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One Third Rack Unit Fiber Optic Transmitter and Receiver

Fiber Optic Link Models

Model Number	Frequency
OL-103000-1	10–3000 MHz
OL-3442-1	3.4–4.2 GHz
OL-95012750-1	0.95–12.75 GHz

Fiber Optic Transmitter Models

Model Number	Frequency
ORT-103000-1	10–3000 MHz
ORT-3442-1	3.4–4.2 GHz
ORT-95012750-1	0.95–12.75 GHz

Fiber Optic Receiver Models

Model Number	Frequency
ORM-103000-1	10–3000 MHz
ORM-3442-1	3.4–4.2 GHz
ORM-95012750-1	0.95–12.75 GHz

For additional information please contact Chris Alfenito at (631) 439-9108 or calfenito@miteq.com

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Broadband Power Amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA018-3000	2.0–18.0	25	6.0	2.0	23	28
JCA218-3001	2.0–18.0	25	6.0	2.0	25	30
JCA218-3002	2.0–18.0	25	6.0	2.0	27	32
JCA218-4000	2.0–18.0	30	6.0	2.0	23	28
JCA218-4001	2.0–18.0	30	6.0	2.0	25	30
JCA218-4002	2.0–18.0	30	6.0	2.0	27	32
JCA218-5000	2.0–18.0	35	6.0	2.0	23	28
JCA218-5001	2.0–18.0	35	6.0	2.0	25	30
JCA218-5002	2.0–18.0	35	6.0	2.0	27	32

Power Amplifiers

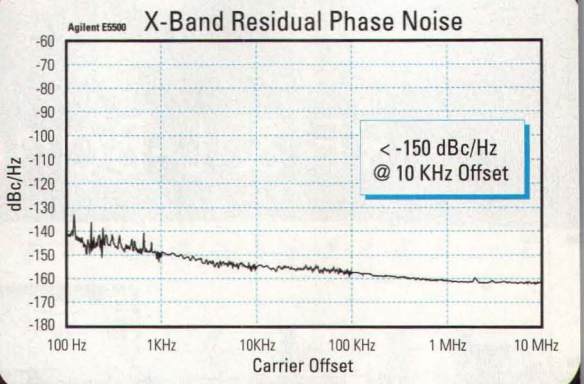
Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA12-P01	1.35–1.85	35	4.0	1.0	33	41
JCA34-P02	3.1–3.5	40	4.5	1.0	37	45
JCA56-P01	5.9–6.4	30	5.0	1.0	34	42
JCA812-P03	8.0–12.0	40	5.0	1.5	33	40
JCA1218-P02	12.0–18.0	22	4.0	2.0	25	35

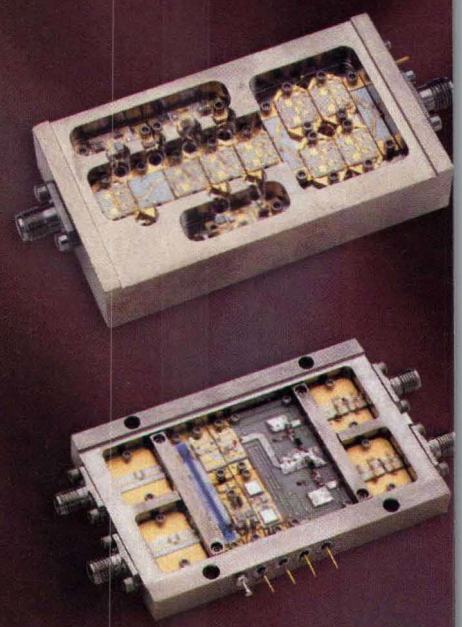
Low Noise Amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA12-1000	1.2–1.6	25	0.8	0.5	10	20
JCA12-3001	1.0–2.0	40	0.8	1.0	10	20
JCA23-302	2.2–2.3	30	0.8	0.5	10	20
JCA34-301	3.7–4.2	30	1.0	0.5	10	20
JCA78-300	7.25–7.75	27	1.2	0.5	13	23
JCA910-3000	9.0–9.5	25	1.3	0.5	13	23
JCA1112-3000	11.7–12.2	27	1.4	0.5	13	23
JCA1415-3001	14.4–15.4	35	1.6	1.0	14	24
JCA1819-3001	18.1–18.6	25	2.0	0.5	10	20
JCA2021-3001	20.2–21.2	25	2.5	0.5	10	20

Millimeter Wave Amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA2629-201	26.0–29.0	19	5.0	1.5	5	15
JCA2629-401	26.0–29.0	35	5.0	1.5	5	15
JCA2730-205	27.5–30.0	15	5.0	1.0	15	25
JCA2730-302	27.5–30.0	26	5.0	1.0	8	18
JCA2730-502	27.5–30.0	43	5.0	1.0	8	18
JCA3031-102	30.0–31.0	18	5.0	1.5	8	18
JCA3031-302	30.0–31.0	34	5.0	1.5	8	18
JCA3031-405	30.0–31.0	40	5.0	1.5	15	25
JCA2640-301	26.5–40.0	30	5.0	2.5	0	10





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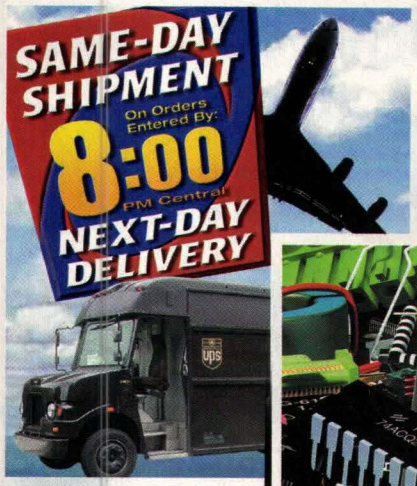

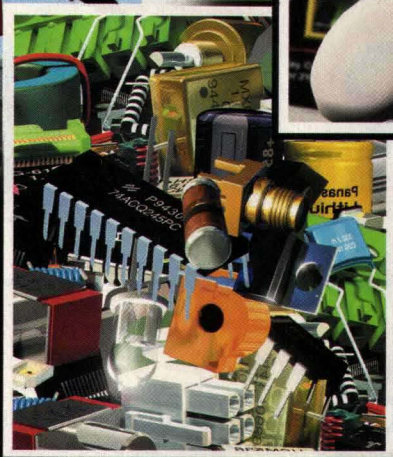

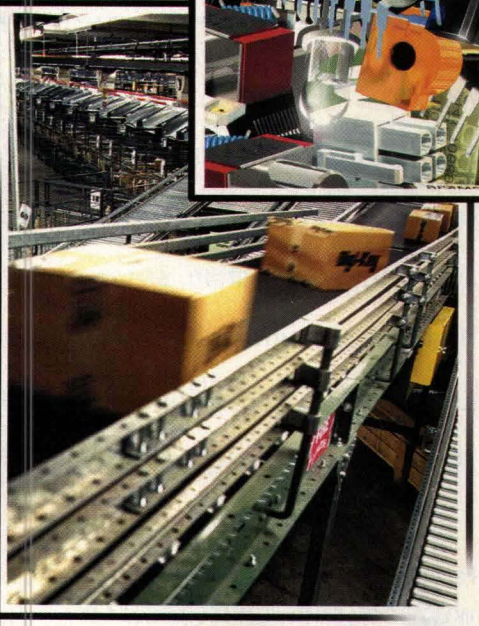

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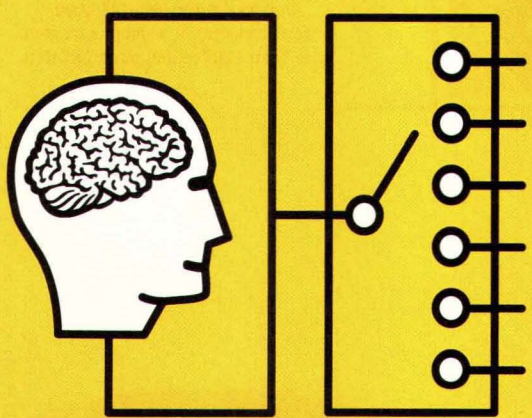

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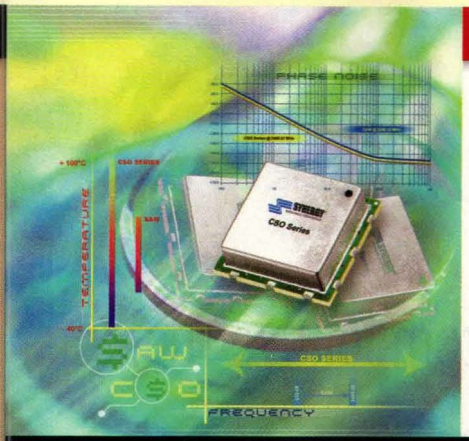

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Microwaves & RF (ISSN 0745-2993) is published monthly, except semi-monthly in December. Subscription rates for US are $80 for 1 year ($105 in Canada, $140 for International). Published by Penton Media, Inc., The Penton Building, 1300 E. 9th St., Cleveland, OH 44114-1503. Periodicals Postage Paid at Cleveland, OH and at additional mailing offices.

Canada Post International Publications Mail (Canadian Distribution Sales Agreement #400268800). Canadian GST #R126431964.

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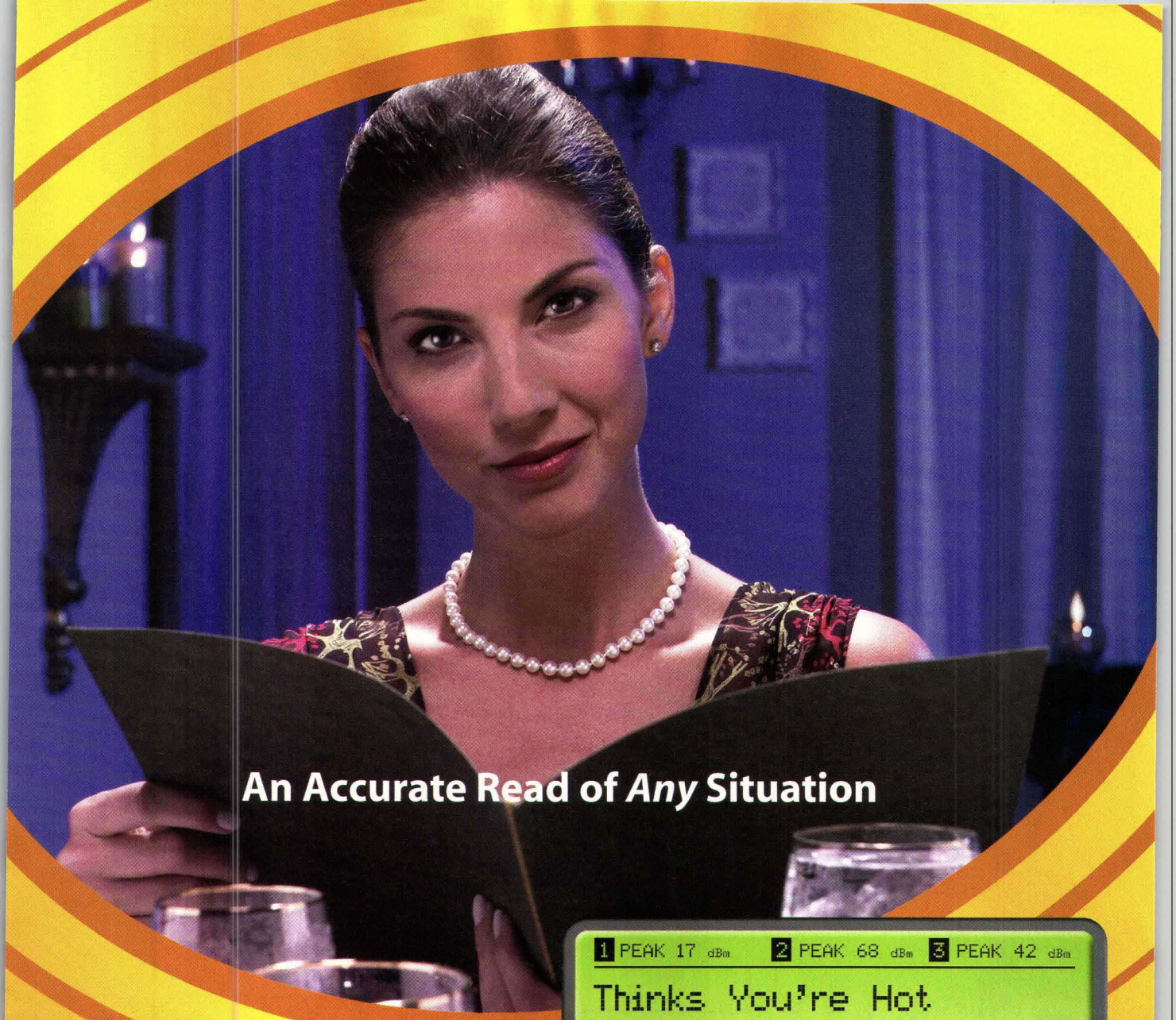

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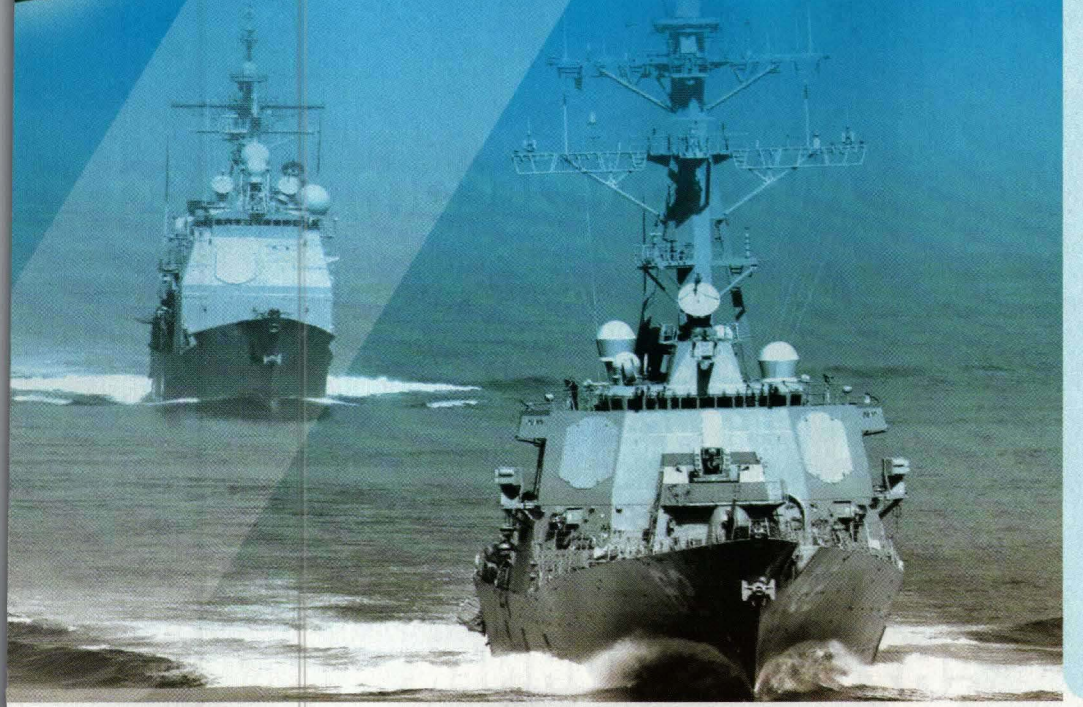

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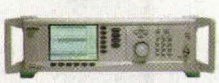

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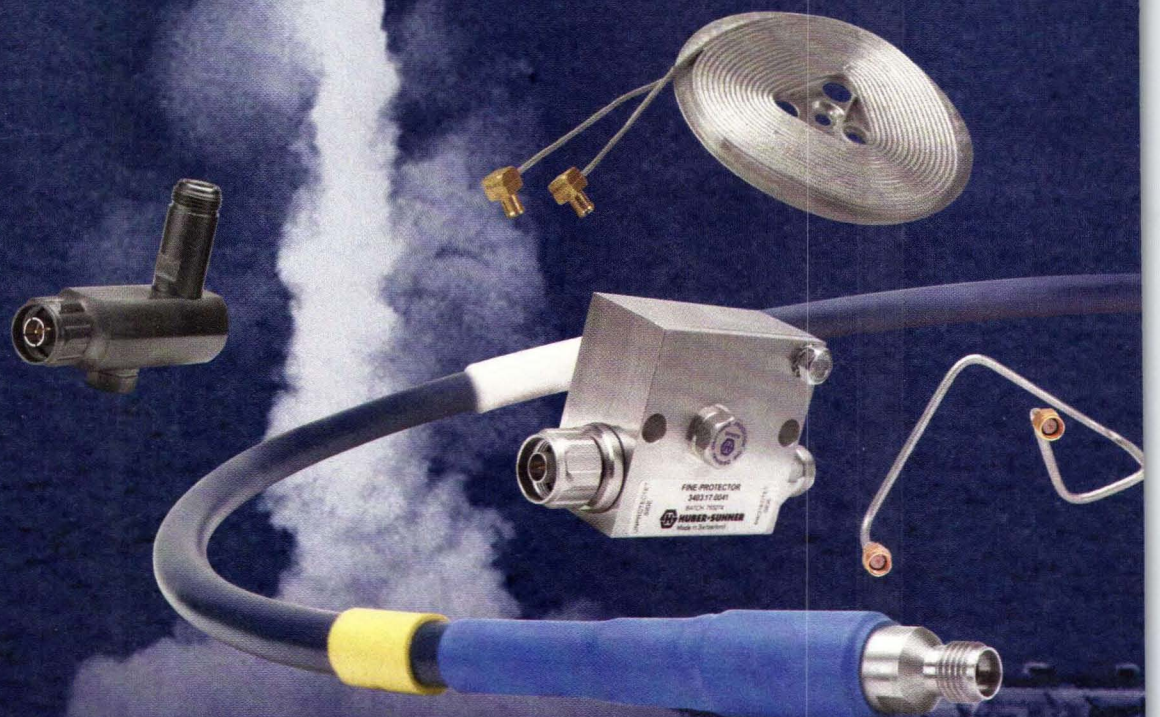

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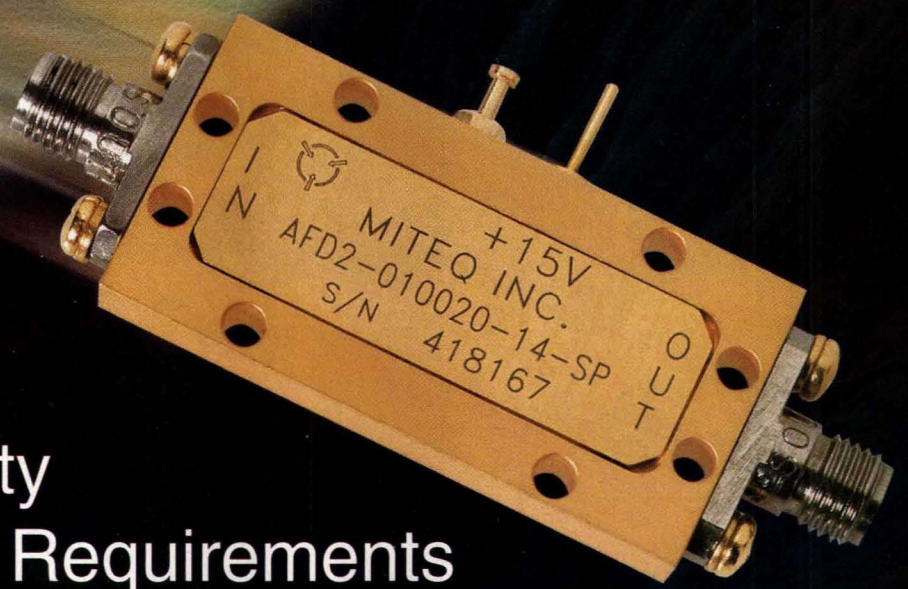

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MODEL NUMBER	FREQ. (GHz)	GAIN (dB, Min.)	GAIN FLATNESS (±dB, Max.)	NOISE FIGURE (dB, Max.)	IN/OUT VSWR	POWER OUT (dBm, Min.)	CURRENT (mA, Typ.)
AFD2-010020-14-SP	1–2	20	1.50	1.4	2.0:1	+10	100
AFD3-010020-14-SP	1–2	34	1.25	1.4	2.0:1	+10	120
AFD3-022023-12-SP	2.2–2.3	30	0.50	1.2	1.5:1	+10	100
AFD3-023027-12-SP	2.3–2.7	30	0.50	1.2	1.5:1	+10	100
AFD3-027031-12-SP	2.7–3.1	30	0.50	1.2	1.5:1	+10	100
AFD3-031035-12-SP	3.1–3.5	30	0.50	1.2	1.5:1	+10	100
AFD3-037042-12-SP	3.7–4.2	30	0.50	1.2	1.5:1	+10	100
AFD3-040080-35-SP	4–8	24	1.25	3.5	2.0:1	+10	150
AFD3-020080-40-SP	2–8	23	1.50	4.0	2.0:1	+10	150
AFD3-040120-55-SP	4–12	18	1.50	5.5	2.0:1	+10	150
AFD3-080120-50-SP	8–12	18	1.25	5.0	2.0:1	+10	150
AFD1-010020-23P-SP	1–2	11	1.00	4.0	2.0:1	+23	275
AFD2-010020-23P-SP	1–2	25	1.50	3.5	2.0:1	+23	400
AFD3-020027-23P-SP	2.0–2.7	22	1.25	4.5	2.0:1	+23	350
AFD3-027031-23P-SP	2.7–3.1	22	1.25	4.5	2.0:1	+23	350
AFD3-031042-23P-SP	3.1–4.2	22	1.25	4.5	2.0:1	+23	350
AFD3-040080-23P-SP	4–8	20	1.25	5.5	2.0:1	+23	350
AFD3-020080-20P-SP	2–8	18	1.50	6.0	2.0:1	+20	350
AFD3-080120-20P-SP	8–12	15	1.50	6.5	2.0:1	+20	350
AFD3-040120-18P-SP	4–12	15	1.75	6.5	2.0:1	+18	350

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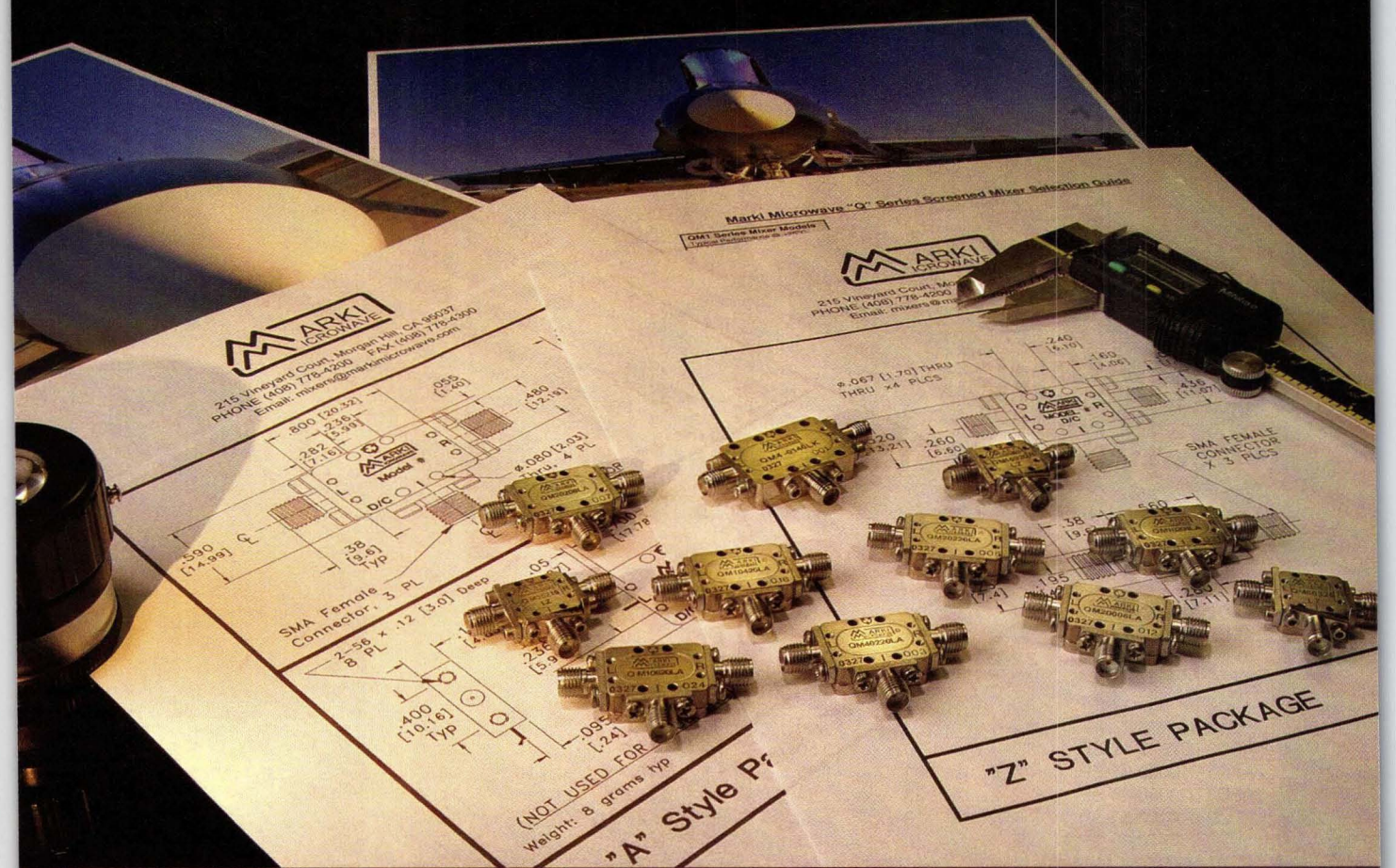

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E-Mail Correction

▶▶I JUST SAW my "corrections" in the June issue. I still see a problem with my e-mail address—it's not crc006@email.mpt.com as shown in the magazine but crc006@email.mot.com.

Rich Carlson
Motorola

Editor's Note: The incorrect e-mail address that was given for Mr. Carlson in our June issue was due to a typographical error. We apologize to Mr. Carlson and to our readers for any confusion that this may have caused.

Infocenter Errors

▶▶THE INFOCENTER PAGE of the July issue featured several errors. The two listings for Ansoft Corp. gave the incorrect Web address, as did the listings for Anderson Electronics, Inc. and Anaren Microwave, Inc.

Ansoft's Web address should have been listed as www.ansoft.com/ansoftdesigner.

Anderson Electronics, Inc.'s Web address is www.aextal.com. Anderson's e-mail address is sales@aextal.com.

Anaren Microwave's Web address should be www.anaren.com.

We apologize to the companies involved and to our readers for these errors. In addition, it should be noted that should a reader ever have trouble locating a company's website, the magazine publishes an annual directory in December, the *Microwaves & RF Product Data Directory* issue, which provides comprehensive listings of high-frequency companies' addresses, telephone numbers, FAX numbers, e-mail addresses (usually for sales departments) and Web addresses.

Also, the on-line version of the *Microwaves & RF Product Data Directory*, at www.m-rf.com, provides active links to many of the companies advertising in *Microwaves & RF*, along with listings of Web sites for thousands of high-frequency manufacturers, as well as nearly 1000 new product writeups, which can be searched according to company or product category.

The Editors of Microwaves & RF

PLEASE COMMENT

Microwaves & RF welcomes mail from its readers. Letters must include the writer's name and address. The magazine reserves the right to edit letters appearing in "Feedback." Address letters to:

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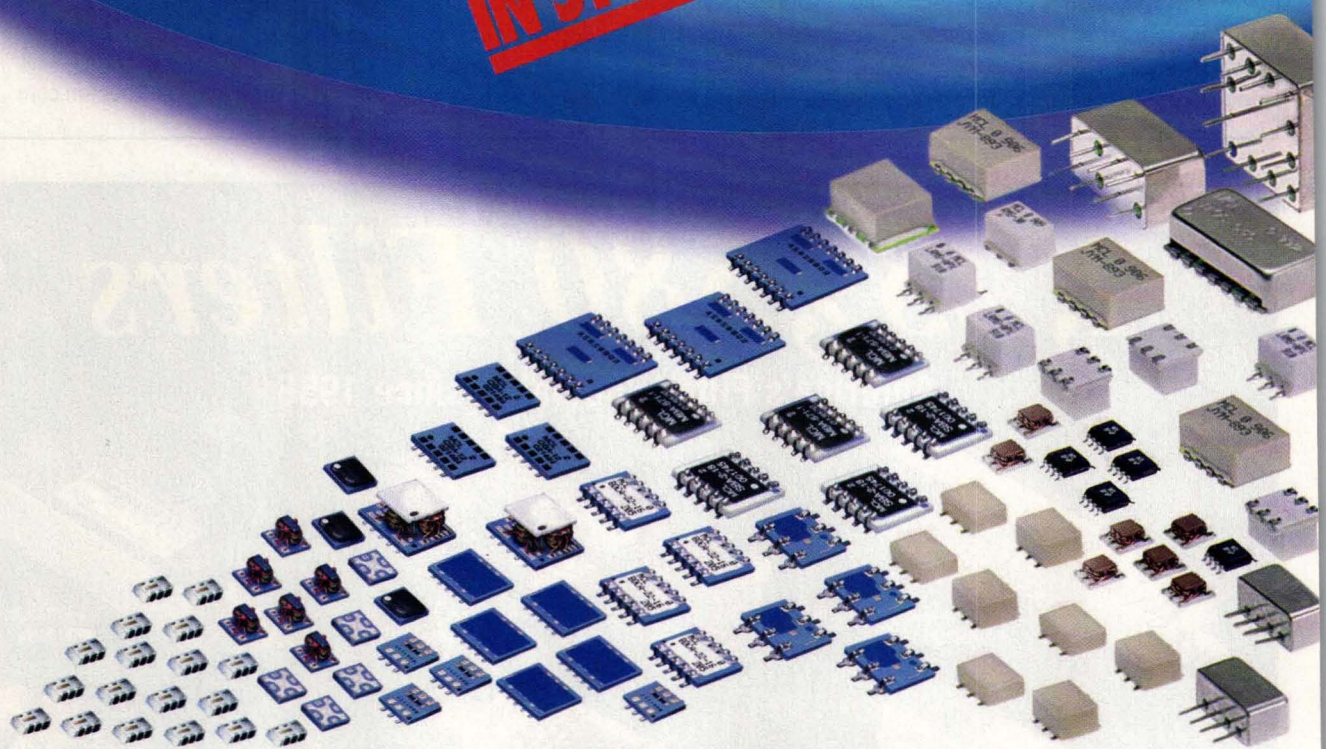

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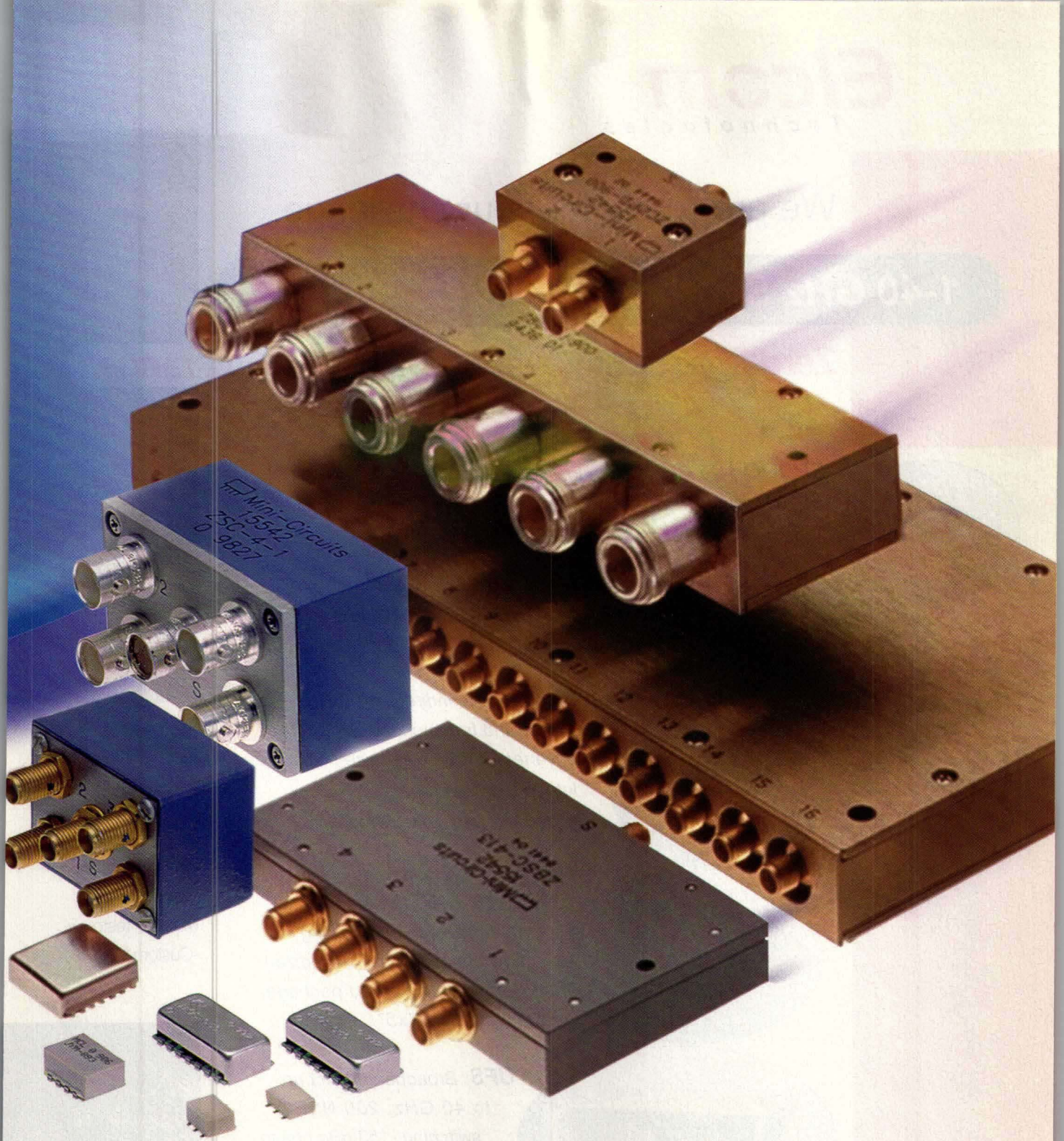

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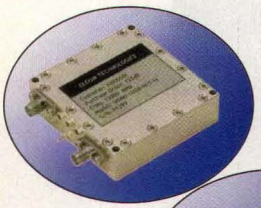

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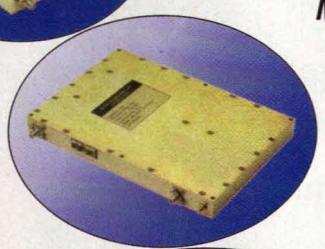

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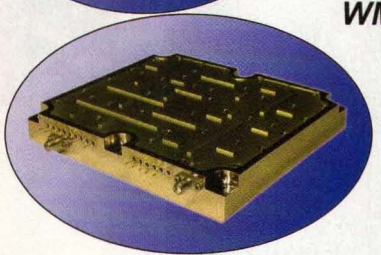

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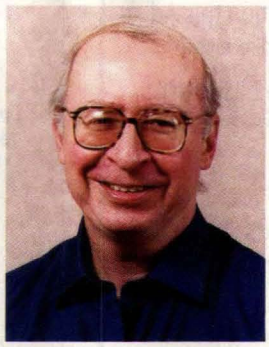
Learning More About Military Electronics



MILITARY ELECTRONICS NOW triggers the automatic interest among high-frequency design engineers that the term "wireless communications" generated a decade earlier. During that time, many companies abandoned their military business efforts for wireless, leaving a smaller number of military component and subsystem suppliers. Those who remained in the business, however, found the flow of military business to be steady and reliable.

As this issue recognizes the importance of military electronics to the high-frequency industry, it is also fitting that it should mark the third gathering of the Military Electronics Show (MES) in the Baltimore Convention Center (Baltimore, MD, September 16-17). The MES has been a humble attempt to support the educational needs of engineers and engineering managers working in the military electronics field, and special thanks are due to the many dedicated professionals who agreed to make technical presentations at this year's event.

The MES has been a humble attempt to support the educational needs of engineers and engineering managers working in the military electronics field.

In particular, appreciation goes to the MES Keynote Speaker, Jim Tung, chief market development officer for The MathWorks. Jim's company, of course, is a well-known supplier of mathematical modeling software that is widely used by RF/microwave engineers (especially those working on antennas) to predict the field behavior and performance of complex structures. Jim's talk will detail the growing complexity in system development, in which a combination of controls, signal and image processing, communications circuitry, and other technologies are needed to satisfy sophisticated requirements.

Although the MES has been steadily growing in size from year to year, it is still a relatively small event in terms of electronic trade shows. But the philosophy that guides the technical conference and exhibition hall is sound: to provide continuing education about the latest technologies and engineering approaches impacting design engineers working in military electronics. Of course, this charter represents a wide expanse of technologies, since the electronic content of military systems includes everything from amplifiers and antennas to power supplies and video display screens. Covering that much technology in any single event would be a daunting task. But over time, as the MES grows, its technical organizers will make every effort to provide coverage of the many different electronic components and subsystems within modern and emerging military systems.

As for this year's MES, the program is small but strong (see the preview on p. 33), and hopefully will provide meaningful information to MES attendees.

Jack Browne

Publisher/Editor

Microwaves & RF

A Penton Publication

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Microwaves & RF is sent free to individuals actively engaged in high-frequency electronics engineering. In addition, paid subscriptions are available. For paid subscription requests, please contact: Penton Media Inc., P.O. Box 2135, Skokie, IL 60076-7835. For all other Customer Service inquiries, contact: Penton Media Inc., P.O. Box 2095, Skokie, IL 60076-7995.

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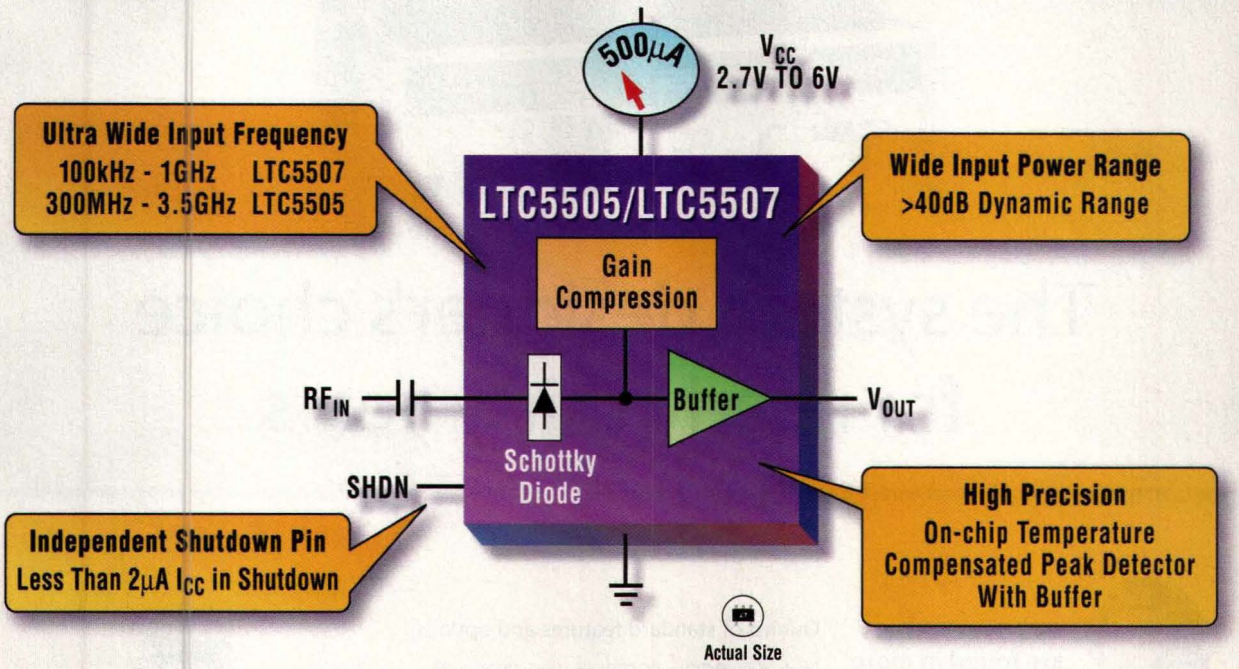

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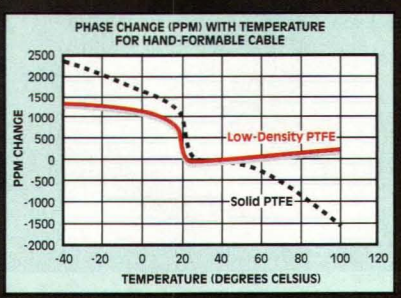

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IL 10.0 GHz	66.4	37.9

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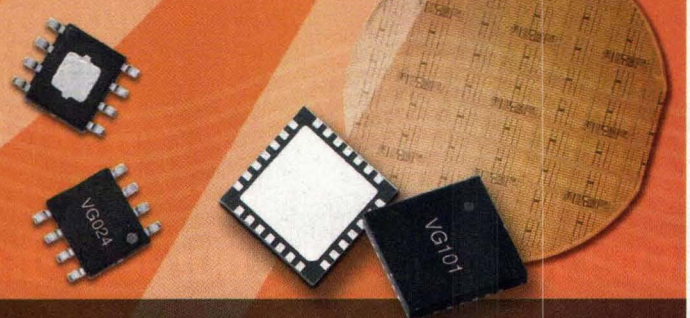

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VG101	750-1000	28	14.0	37	21	4.2	150	0-4.5	5	28-PIN QFN
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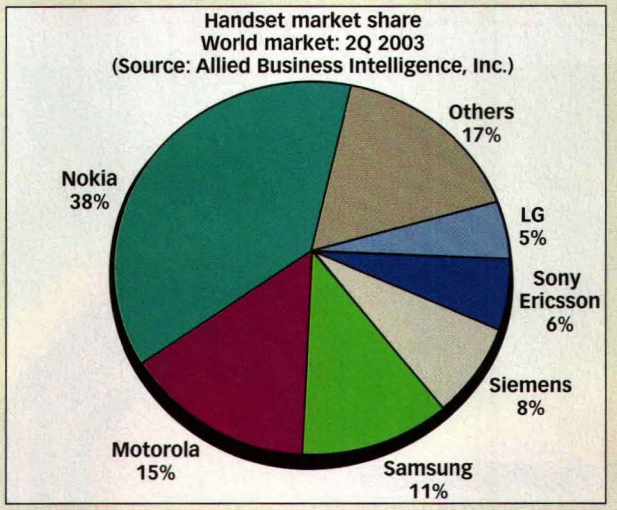
the front end

News items from the communications arena.

Total Handset Market Increases To 107 Million Units, Says ABI

OYSTER BAY, NY—In Q2 2003, the total handset market increased to 107 million units, demonstrating a marginal increase of 2 percent sequentially and 12-percent growth year-on-year, according to Allied Business Intelligence, Inc. (ABI). Nokia continued to lead the market with a 38-percent market share. ABI believes that the surge in handset shipments is fueled by new features like color screens and camera phones, and that replacement shipments account for nearly two-thirds of all handsets shipped.



Nokia shipped over a third of its shipments with color screens, and Samsung clocked a 45-percent penetration with color screens among its shipments. ABI estimates that this trend will continue, and color screens will account for about 96 percent of all shipments by 2008.

Sony Ericsson had a dramatic comeback with 6.7 million handset shipments, grabbing the fifth position from LG Electronics. The company's ASP (average selling price) also rose from $167 to $190. However, while Nokia and Sony Ericsson showed growth in shipments sequentially, Siemens showed no improvements, with shipments at 8.1 million units and the lowest ASP among the top handset makers at $130. ABI continues to believe that ASPs will come under increased pressure, despite additional handset features.

ABI estimates that nearly 3.6 million units of smartphones and smartphone-PDAs were sold in Q2 2003, representing about 3.3 percent of the overall handset market.

Auto Applications Help Drivers Avoid Objects In The Road

ROGERS, CT—Rogers Corp. has announced that a variety of its materials have been designed into automotive applications that assist today's drivers to avoid both moving and stationary objects, as well as provide improved comfort and convenience.

Rogers' RT/duroid® 5880 high-frequency circuit materials are being used in "adaptive cruise control" systems that typically operate at 77 GHz. With a car's cruise control engaged, these new "active" systems use radar technology to automatically adjust the speed of the car to that of the car ahead of it. This feature assists the driver in maintaining a safe, comfortable distance between vehicles, even under poor visibility conditions.

A number of other high-frequency circuit materials manufactured by Rogers are used in other "smart car" applications, including radar systems that alert drivers to stationary objects in the front, rear, or side of the car; devices that measure the amount of air in tires and inform the driver when pressure is too low; antennas for ID tags that can be used in automatic payment systems like those used for toll booths; and Global Positioning Systems (GPS) that can provide traffic information, directions, or driver-in-trouble assistance.

Rogers Corp.'s president and COO, Robert D. Wachob, comments, "We continue to develop new ways for our materials to suit the rapidly growing needs of these evolving technologies. As a result, Rogers' sales into this new 'smart car' market will exceed $1 million this year and are expected to grow quite dramatically in the years ahead."

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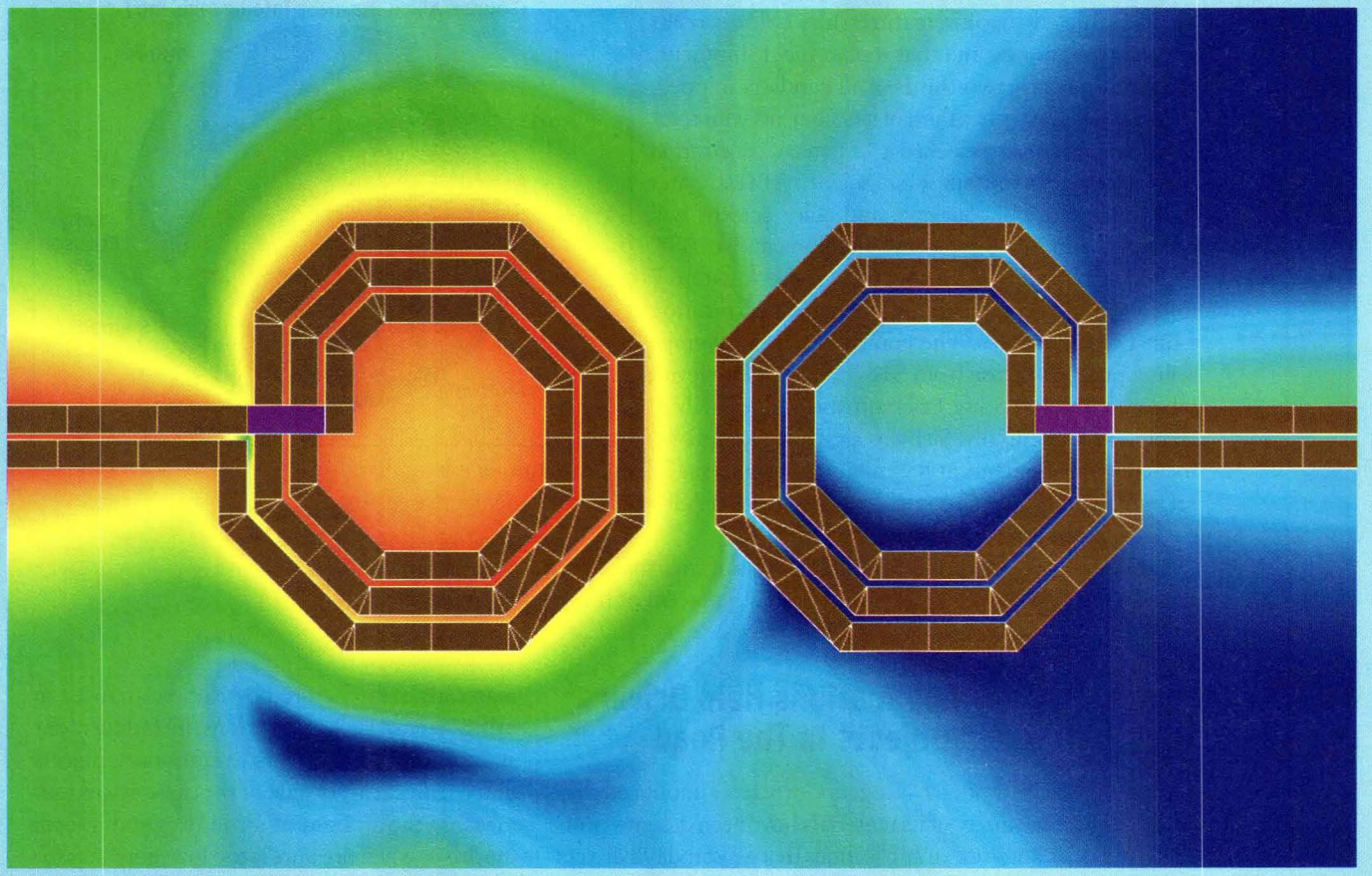

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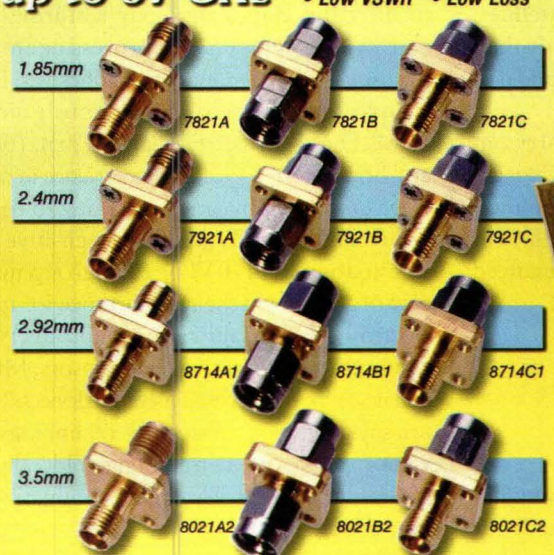

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M/A-COM Extends Relationship With The Ford Motor Company

LOWELL, MA—M/A-COM, a business unit of Tyco Electronics and a provider of RF and microwave components, has announced an agreement with Ford Motor Co. to provide Global Positioning System (GPS) navigation-system antennas for several of Ford's vehicle lines, according to a report from PR Newswire.

"We are pleased to be providing Ford Motor Co. with this GPS Technology," says Dave Williams, director of Automotive Sensors and Telematics at M/A-COM. "This agreement is a testament to our technology's reliability across the industry and our ability to meet our customers' on-going production timelines. We have an established history of working with Ford and we are looking forward to continuing our relationship."

"Global-positioning technology has been one of the hottest new technologies for the automotive industry and a significant driver for new features."

Under terms of the agreement, M/A-COM's GPS antennas will be installed across several Ford, Lincoln, and Mercury vehicle platforms. The internally mounted antennas provide GPS reception for customer convenience services such as onboard mapping and destination routing.

In the past several years, global-positioning technology has been one of the hottest new technologies for the automotive industry and a significant driver for new features. Using geosynchronous Global Positioning satellites, vehicles with receivers are able to identify their exact location to plot driving directions and destination courses.

Many modern automobiles now carry onboard navigation systems using GPS. Consisting of a single antenna element and amplifier, these GPS antenna products are available for interior or exterior mounting and can be cabled for a variety of automotive platforms.

Wireless Solution Suits Urban Environments

SUNNYVALE, CA—Proxim Corp., a manufacturer of wireless networking equipment for Wi-Fi and wireless wide-area networking, has produced the Proxim Tsunami MP.11a, an affordable and secure outdoor wireless solution for service providers and enterprises that offers 54 Mb/s data rates in three separate 5-GHz frequency bands for global deployments. It also offers non-line of site capabilities for urban environments with dense populations.

"Proxim's Tsunami MP.11a raises the bar by offering outdoor wireless performance levels and features that are unmatched in the industry at a price that is very affordable," states Kevin Duffy, senior vice president of R&D and product-line management for Proxim. "the increased spectrum and data rates offered by the Tsunami MP.11a enable applications including multi-camera security and surveillance networks, high-density metropolitan networks, data backhaul, and last-mile access that can be deployed globally."

The Tsunami MP.11a offers 54 Mb/s data rates with up to 30 Mb/s effective bandwidth. It provides the OFDM modulation, Transmit Power Control, and Dynamic Frequency Selection features required for European deployments.

The Tsunami MP.11a Base Station Unit has a US list price of $1295. The Tsunami MP.11a Subscriber Unit has a US list price of $695, and the Tsunami MP.11a Residential Subscriber Unit has a US list price of $495.

New Company Advances Flip Chip Assembly Method

BILLERICA, MA—Polymer Assembly Technology (PAT), a new company founded by industry veteran Jim Clayton, has opened its doors to offer flip chip technology featuring high-density, low-temperature processing through the use of polymer conductive adhesives. PAT's founder and president was previously director of R&D at Polymer Flip Chip Corp. (PFCC) and brings over 30 years of experience in microelectronic assembly and packaging to bear on this technology. "Temperature-sensitive polymer coatings and II-VI or III-V group materials are growing in their importance for microelectronic device fabrication, in products such as optical-, radiation-, and bio-sensors, MEMS, and newer polymer-based memory devices," Clayton says. "Polymer Assembly Technology provides an alternative to traditional solder flip chip assembly by using electrically conductive and non-conductive inks that can be stencil printed and cured at temperatures as low as 80°C." This alternative flip chip is timely, since newer no-lead solder alloys are pushing processing temperatures well above 250°C, placing additional strain on fragile components.

PAT is presently assisting a number of private and government labs developing X-ray detectors and IR Focal Plane Arrays.

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Models		Attenuation* (dB)				
SMA-M/F DC-6GHz	*BNC-M/F DC-2GHz*	Nominal	Flatness Midband	Flatness Typ.	**VSWR** (:1) Midband	**VSWR** (:1) Typ.
VAT-1	HAT-1	1	1	0.20	0.11	1.10	1.2
VAT-2	HAT-2	2	2	0.20	0.10	1.20	1.2
VAT-3	HAT-3	3	3	0.15	0.12	1.15	1.1
VAT-4	HAT-4	4	4	0.15	0.08	1.15	1.1
VAT-5	HAT-5	5	5	0.10	0.06	1.15	1.1
VAT-6	HAT-6	6	6	0.10	0.02	1.15	1.1
VAT-7	HAT-7	7	7	0.10	0.05	1.15	1.1
VAT-8	HAT-8	8	8	0.10	0.04	1.20	1.1
VAT-9	HAT-9	9	9	0.10	0.02	1.15	1.1
VAT-10	HAT-10	10	10	0.20	0.03	1.20	1.1
VAT-12	HAT-12	12	12	0.10	0.05	1.20	1.1
VAT-15	HAT-15	15	15	0.30	0.05	1.40	1.1
VAT-20	HAT-20	20	20	0.75	0.18	1.20	1.1
VAT-30	HAT-30	30	30	0.30	0.38	1.15	1.1

Power: 0.5W at 70°C ambient.
* Attenuation varies by ±0.3dB max. (VAT), ±0.2dB max. (HAT) over temperature.

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K3-VAT: *2 of Ea. VAT-3, -6, -10 (6 total) $59.95*

K1-HAT: *1 of Ea. HAT-3, -6, -10, -20, -30 (5 total) $48.95*
K2-HAT: *1 of Ea. HAT-1, -2, -3, -4, -5, -6, -7, -8, -9, -10 (10 total) $97.95*
K3-HAT: *2 of Ea. HAT-3, -6, -10 (6 total) $58.95*

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Motorola's Security Measures Aid Emergency Communications

BASINGSTOKE, UNITED KINGDOM—Motorola, Inc. Commercial, Government and Industrial Solutions Sector (CGISS) has announced the introduction of a new range of security products for TETRA (TErrestrial Trunked RAdio) digital radio systems that will further protect emergency services' communications. The new suite of software products, named Dimetra SecureNet™, provides an important new level of protection against criminal eavesdropping on communications, impersonating officers on the air, and deliberate clogging of radio systems at crucial times.

"Security of communications is essential to our operations."

Motorola, which was the first company to deploy TETRA encryption three years ago, have achieved another milestone by being the first to have Class 3 encryption on trial with the Police Service of Northern Ireland.

The Police Service of Northern Ireland, who already have highly secure digital radio communications systems, have upgraded the protection of their new TETRA communications to Class 3 encryption. A spokesperson at the Police Service of Northern Ireland comments, "Security of communications is essential to our operations and this upgrade to our system, which is currently undergoing installation, is part of a program to give us the most secure wide-area police-communications system in the British Isles."

In mainland Britain, 11 police forces using Motorola-supplied TETRA digital radio-communications systems operated by mmO2 Airwave are protected against eavesdropping by encryption. Analogue systems used by the remainder of the emergency services in the UK, consisting of 40 police forces as well as all ambulance and fire services, do not have the added protection of digital and encrypted communication and remain vulnerable to eavesdropping via scanning devices.

Increasingly, criminals are eavesdropping on emergency services to gain advance warning of action against them, and it is difficult to keep major operations secret if any of the forces involved are not using encrypted digital radio. This can have a major impact on police operations efficiency, as a UK police force recently discovered when they changed to their new Airwave system and achieved an immediate positive impact on their success in fighting drug-related crime.

Although ETSI Class 3 encryption has been available for test and demonstration purposes for some time, Motorola is the first company to roll out ETSI Class 3 encryption in its Dimetra SecureNet system. The Dimetra SecureNet system uses embedded encryption measures to protect not just the transmission content, but also user identities and signalling data. This means that people using scanners cannot eavesdrop or track users and cloned radios cannot be used for misinformation.

Kudos

PITTSBURGH, PA—Ansoft Corp. director Dr. Ulrich L. Rohde received a Marconi Memorial Gold Medal of Achievement from the Veteran Wireless Operators Association (VWOA) for his exemplary achievements in the field of microwave circuit simulation and design.

Dr. Rohde, who has served on Ansoft's board of directors since 1997, has more than 20 years of experience with microwave circuit theory and technology. An Institute of Electrical and Electronics Engineers (IEEE) fellow, he has published numerous articles and books on the subject and has lectured throughout North America, Europe, and Asia. Formerly the president and CEO of Compact Software, Inc., Dr. Rohde currently is president of Communications Consulting Corp., chairman of Synergy Microwave Corp., a partner of Rohde & Schwarz, and a member of the faculty of several universities.

GREENSBORO, NC—RF Micro Devices, Inc. (RFMD) announced that Gartner Dataquest has recognized RF Micro Devices as the industry's number one provider of power amplifiers (PAs) for wireless handsets based on 2002 revenues. According to a June 2003 report entitled, "Wireless Communications Semiconductor Competitive Market Shares for 2002," Gartner Dataquest estimated that the worldwide PA market in 2002 was approximately $1.09 billion, of which Gartner estimates RFMD held approximately 35 percent market share.

LONDON, ENGLAND—Smiths Interconnect—Sabritec, a customer connector manufacturer, has announced their certification to ISO 14001.

Sabritec has pursued an environment-friendly way of doing business, trying to prevent pollution and reducing the consumption of resources whenever practical. Sabritec's Certificate of Certification is valid through July 2006. MRF

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DC-5.5	18.7	33.7	13.8	4.8	SBA-4086	
DC-5.0	19.4	34.7	16.9	4.4	SBA-5086	
DC-5.5	18.7	33.5	14.5	4.8		SBA-4089
DC-5.0	19.3	34.1	17.9	4.5		SBA-5089

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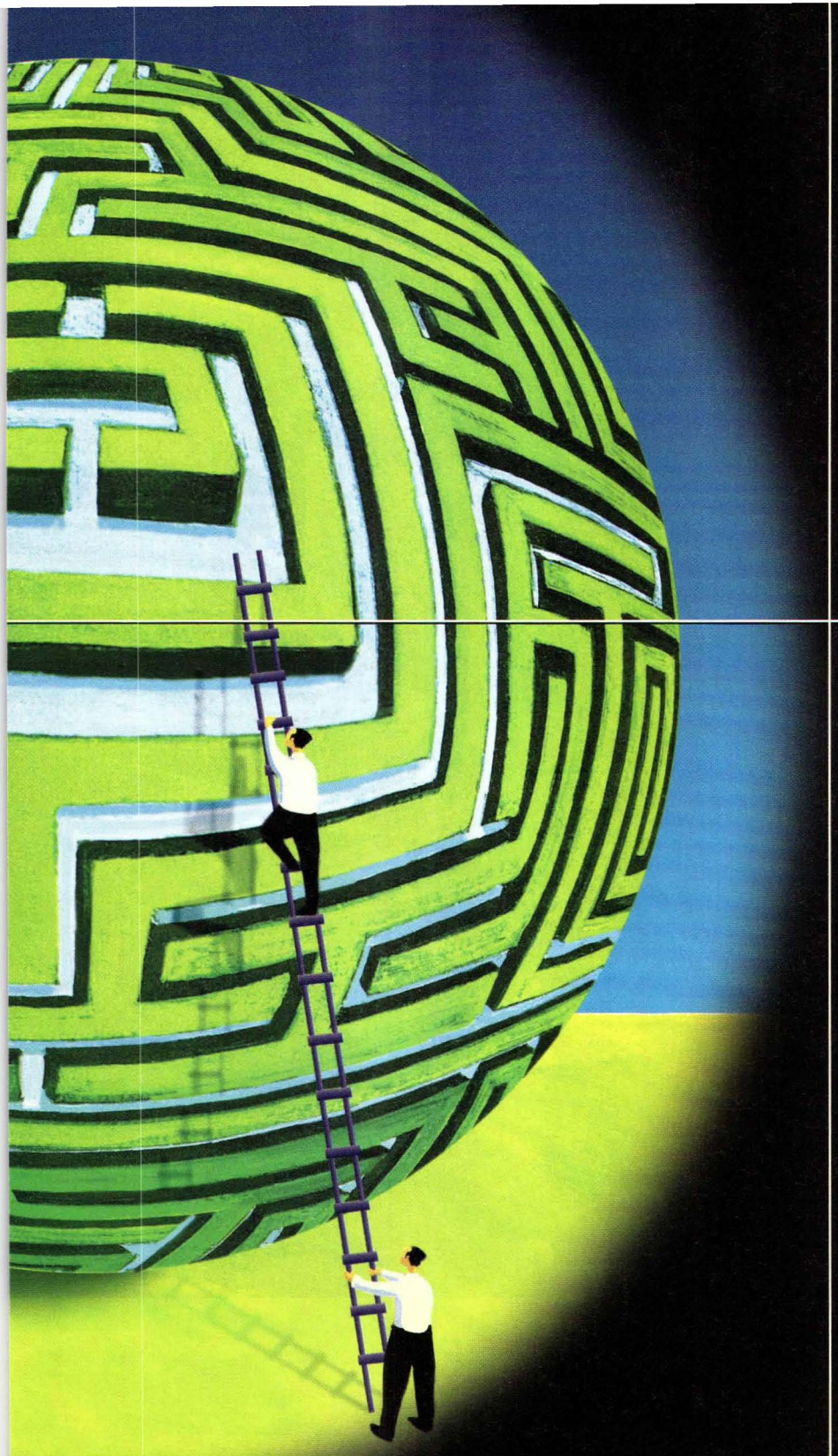

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NEWS

Show Tracks Changing Military Requirements

The Third Annual Military Electronics Show (MES) promises a strong educational program for engineers and engineering managers tasked with military systems designs.

Military electronics markets have remained strong during the last few years, even at a time when business in commercial optical and wireless communications has slowed to a crawl. To provide designers of military electronics systems an opportunity to catch up on the latest developments in hardware, software, and test equipment, the Military Electronics Show was started three years ago to provide a technical conference for continuing education and a meeting place for buyers and sellers of the hardware and software used in the design of military electronics systems.

JACK BROWNE
Publisher/Editor

Scheduled for September 16-17, 2003 in the Baltimore Convention Center (Baltimore, MD), the Third Annual MES offers a diversified technical program and a strong lineup of military suppliers in the exhibition hall. Exhibitors include leading materials, components, software, and test-equipment suppliers **(see Exhibitors at a glance)**, and displays of their products and services are certain to attract specifiers from the military design community.

The technical program includes a keynote address by Jim Tung, chief market development officer for The MathWorks, suppliers of mathematical modeling software. His presentation, entitled "Coming to Grips with Complexity in System Development—Collaborative Approaches Using Model-Based Design," addresses the challenges faced by defense-system developers, and how they must make the transition from document-based processes to a model-based approach that integrates algorithm design, system modeling, automatic code generation, and integrated acquisition and analysis.

Conference technical tracks cover such areas as software, systems and subsystems, test and measurement, high-power design, optical communications, and signal processing. In the software track, for example, Sonnet Software founder James Rautio will explain how electromagnetic (EM) analysis tools can be applied to the modeling of difficult components, in this case a spiral inductor.

In the systems and subsystems track, Michael J. Stora, president and CEO, Modular Integration Technologies, Inc., will examine the IEEE-P1552 Structured Architecture for Test Systems (SATS) Standards effort, a multi-dimensional ATE "Open System Platform" packaging specification, that can also be applied to weapon system integration. In addition, Steve Blackman, director of market development for Aerospace and Defense at Wind River Systems, will describe how NASA's JPL suc-

NEWS

Exhibitors at a glance

Exhibitors (booth number)	Web Site	Products
AccelChip (209)	www.accelchip.com	DSP models, software synthesis tools
Advanced Control Components (113)	www.advanced-control.com	DLVAs, logamps synthesizers
Advantest (123)	www.Advantest.com	test equipment
Agile Materials and Technologies,Inc. (121)	www.agilematerials.com	tunable passive components
Amplifier Research (314)	www.amplifiers.com	high-power amplifiers
Anatech Electronics (126)	www.ana-tech.com	precision filters
Anritsu Corporation (114)	www.anritsu.com	test equipment
Applied Engineering Products (313)	www.aepconnectors.com	connectors, cable assemblies
Barry Industries, Inc. (118)	www.barryind.com	thick-film products
Besser Associates (218)	www.besserassociates.com	educational courses
Bird Technologies Group (311)	www.bird-technologies.com	high-power components, power measuring equipment
CAP Wireless, Inc, (206)	www.capwireless.com	amplifiers, subsystems
CMAC MicroTechnology (105)	www.cmac.com	crystal oscillators
Communication Techniques (109)	www.cti-inc.com	oscillators, synthesizers
Cree Microwave (211)	www.cree.com	high-power transistors
Defense Talent Network (220)	www.defensetalent.com	recruitment services
Dielectric Laboratories (109)	www.dilabs.com	capacitors, hybrids
Elanix (217)	www.elanix.com	CAE software
Evans Capacitor Company (203)	www.evanscap.com	high-energy capacitors
Fiber Span (133)	www.fiber-span.com	fiber-optic systems
Filtran Microcircuits (112)	www.filtran	microwave circuitry
Hittite Microwave Corp. (124)	www.Hittite.com	analog/digital ICs
Krytar (204)	www.krytar.com	couplers, detectors, power combiners
Marcel Electronics Intl. (207)	www.mei4pcbs.com	PCBs
MET Laboratories (303)	www.metlabs.com	precision test services
Merrimac Industries (112)	www.merrimacind.com	components, assemblies
Microsemi Corporation (223)	www.microsemi.com	analog, mixed-signal, and discrete semiconductors
Microwave Photonic Systems, Inc. (219)	www.b2bphotonics.com	microwave and optical components, systems
Microwave Technology, Inc. (204)	www.mwtinc.com	GaAs devices, amplifiers
Mid-Atlantic RF Systems (208)	www.midatlanticrf.com	amps, dividers, couplers,switches, synthesizers
Midwest Microwave (120)	www.midwest-microwave.com	attenuators, DC blocks,equalizers, terminations
Modular Components National, Inc. (208)	www.mcn-mmpc.com	single- and double-sided microwave circuits
Northrop Grumman Space Technology (125)	www.northgrum.com	GaAs and InP MMICs, foundry services
Northrop Grumman Electronic Systems (125)	www.northgrum.com	custom prototyping
NOVACAP (212)	www.novacap.com	multilayer ceramic capacitors, high-power capacitors
Q-Tech Corporation (226)	www.q-tech.com	crystal oscillators
Rogers Corporation, Advanced Circuit Materials Division (205)	www.rogerscorporation.com	flexible circuit materials,shielding, laminates
SpectraSite (312)	www.spectrasite.com	towers, in-building wireless systems
TLC Precision Wafer Technology (214)	www.tlcprecision.com	epitaxial wafers
Temptronic Corporation (106)	www.temptronic.com	thermal test systems
Thales Components Corporation (130)	www.thalescomponents.com	T/R modules, ferrite components, tubes
Times Microwave Systems (108)	www.timesmicrowave.com	cables, connectors, cable assemblies
Trilithic, Inc. (213)	www.trilithic.com	attenuators, filters, switches, subsystems
Vectron International (109)	www.milfcp.com	frequency generation and control products
Wireless Valley Communication (224)	www.wirelessvalley.com	wireless design and measurement tools
WL Gore (210)	www.gore.com	cables, shielding, environmental seals

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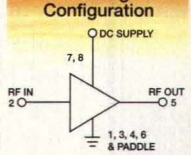

	MODEL	Freq. (GHz)	DC Volts (V)	Gain (dB) @1.5GHz Typ.	Pwr. Out 1dB Comp. (dBm) Typ.	Price $ea. (qty. 30)
ACTUAL SIZE	MNA-2	0.5-2.5	5.0 2.8	12.8 11.2	17.7 12.9	1.90
	MNA-3	0.5-2.5	5.0 2.8	16.1 15.0	11.4 9.7	1.60
	MNA-4	0.5-2.5	5.0 2.8	16.4 14.5	19.0 13.4	1.90
	MNA-5	0.5-2.5	5.0 2.8	21.9 20.5	12.2 10.1	1.60
	MNA-6	0.5-2.5	5.0 2.8	23.6 21.2	18.0 14.1	2.25
	MNA-7	1.5-5.9	5.0 2.8	15.9 13.7	15.6 12.7	2.25
	VNA-21	0.5-2.5	5.0 2.8	13.5 12.3	8.5 7.0	1.80
	VNA-22	0.5-2.5	5.0 2.8	13.8 12.6	17.0 14.0	2.20
	VNA-23	0.5-2.5	5.0 2.8	18.3 17.1	10.0 8.5	1.90
	VNA-25	0.5-2.5	5.0 2.8	18.6 17.4	18.2 12.0	2.50
	VNA-28	0.5-2.5	5.0 2.8	22.8 21.0	11.0 9.6	1.95

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cessfully met an accelerated development schedule on a strict budget for the Mars Pathfinder project, while in a separate presentation, he will review DO-178B guidelines for software in airborne systems and equipment. Also in that systems session, Nino De Falcis of the Temex Time Office, iPrecision Timing Solutions will detail a multireference timing clock called the SynClock that is suitable for synchronizing multiple Stratum 1 references.

In the high-power design track, several presenters will bring attendees up to date on the latest in power semiconductor technologies. For example, Dr. Anthony A. Immorlica, Jr., manager of business development for Advanced Systems and Technology at BAE Systems, will describe his company's research into gallium-nitride (GaN) transistors and discuss the fundamental material properties and drivers that give GaN a decided advantage over silicon and other III-V compound semiconductors. On that same topic, Dr. A.R. Jha, technical director of Jha Technical Consulting Services, will review the unique performance capabilities of high-power microwave GaN High Electron Mobility Transistor (HEMT) devices capable of operating under severe thermal and mechanical environments. In addition, Ramesh K. Gupta, vice president of Advanced Business and Technology for AMCOM Communications, Inc., will discuss high-voltage GaAs power FETS for military applications.

In addition to the half-hour technical sessions, the Third Annual MES will feature several workshops, including a full-day workshop on the first day of the show, "Introduction to Microwave Radar and Electronic Warfare Systems," presented by long-time Besser Associates instructor Al Scott. On the following day, Scott also offers a half-day workshop called "Introduction to Military Electro-Optical Systems," which examines the fundamental engineering characteristics of modern electro-optical systems. More information on the Third Annual Military Electronics Show can be found on the website at www.mes2003.com. MRF

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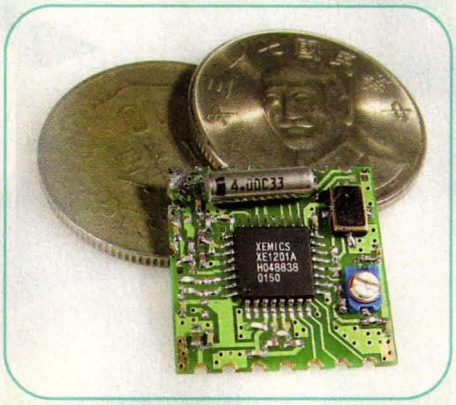
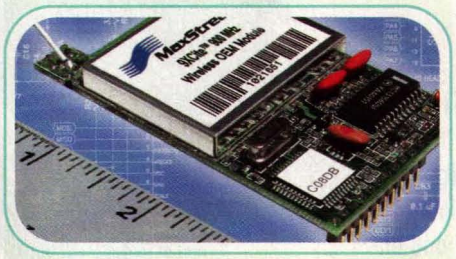
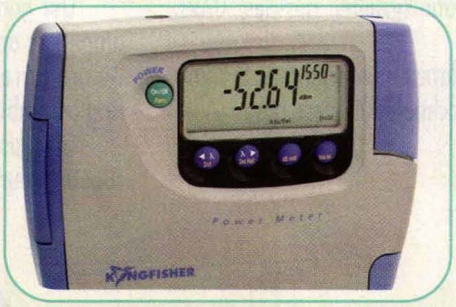


XEMICS' MODEL DP1201A RF TRANSCEIVER MODULE



MAXSTREAM'S MODEL 9XCITE WIRELESS MODULE



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SMALLER THAN A credit card, the model 9Xcite low-cost wireless module is approved by the US Federal Communications Commission (FCC) for frequency-hopping spread-spectrum communications at 900 MHz. The module can also support single-channel TTL or RS-232/422/485 communications. The module, which requires no setup, operates on supplies of +2.85 to +5.5 VDC and generates transmitter power of 1 mW. With its typical receiver sensitivity of –108 dBm, the module achieves a communication range of 90 m in indoor and urban environments and nearly 300 m in outdoor line-of-sight applications with a dipole antenna. It delivers selectable data throughput rates of 9.6 and 38.4 kb/s and features current draw of less than 50 mA in receive mode and only 20 µA in its power-down mode. P&A: $37.00 (1000 qty.).

MaxStream, Inc., 1215 South 1680 West, Orem, UT 84058; (866) 765-9885, (801) 765-9885, FAX: (801) 765-9895, e-mail: lonny@maxstream.net, Internet: www.maxstream.net.

Palm-Sized Meter Measures Optical Power

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Kingfisher International P/L, 30 Rocco Dr., Scoresby, Victoria 3179, Australia; (61) 39757-4100, FAX: (61) 39757-3193, e-mail: sales@kingfisher.com.au, Internet: www.kingfisher.com.au.

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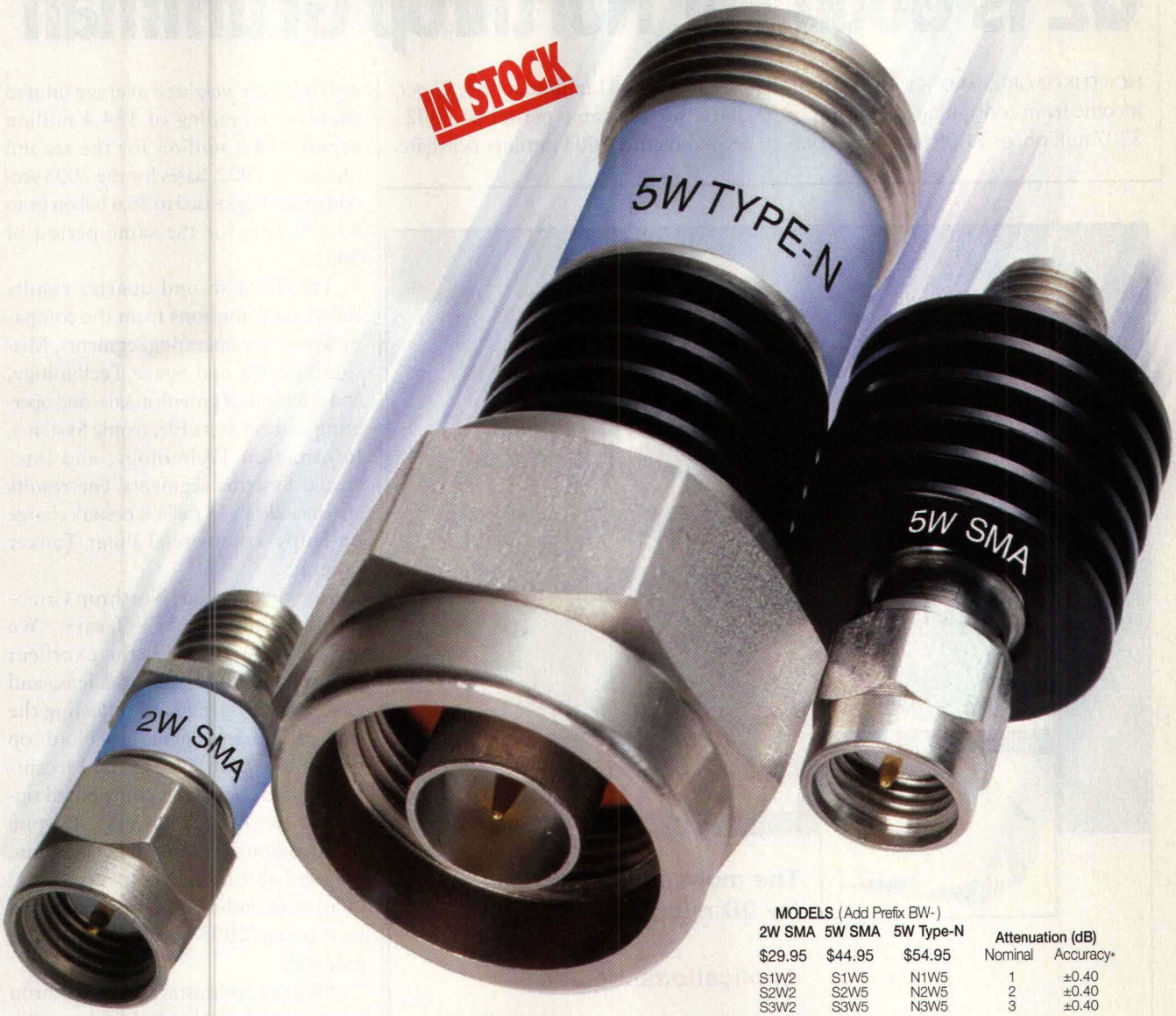

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S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	±0.60
S30W2	S30W5	N30W5	30	±0.85
S40W2	S40W5	N40W5	40	±0.85

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Q2 Is Good For Northrop Grumman

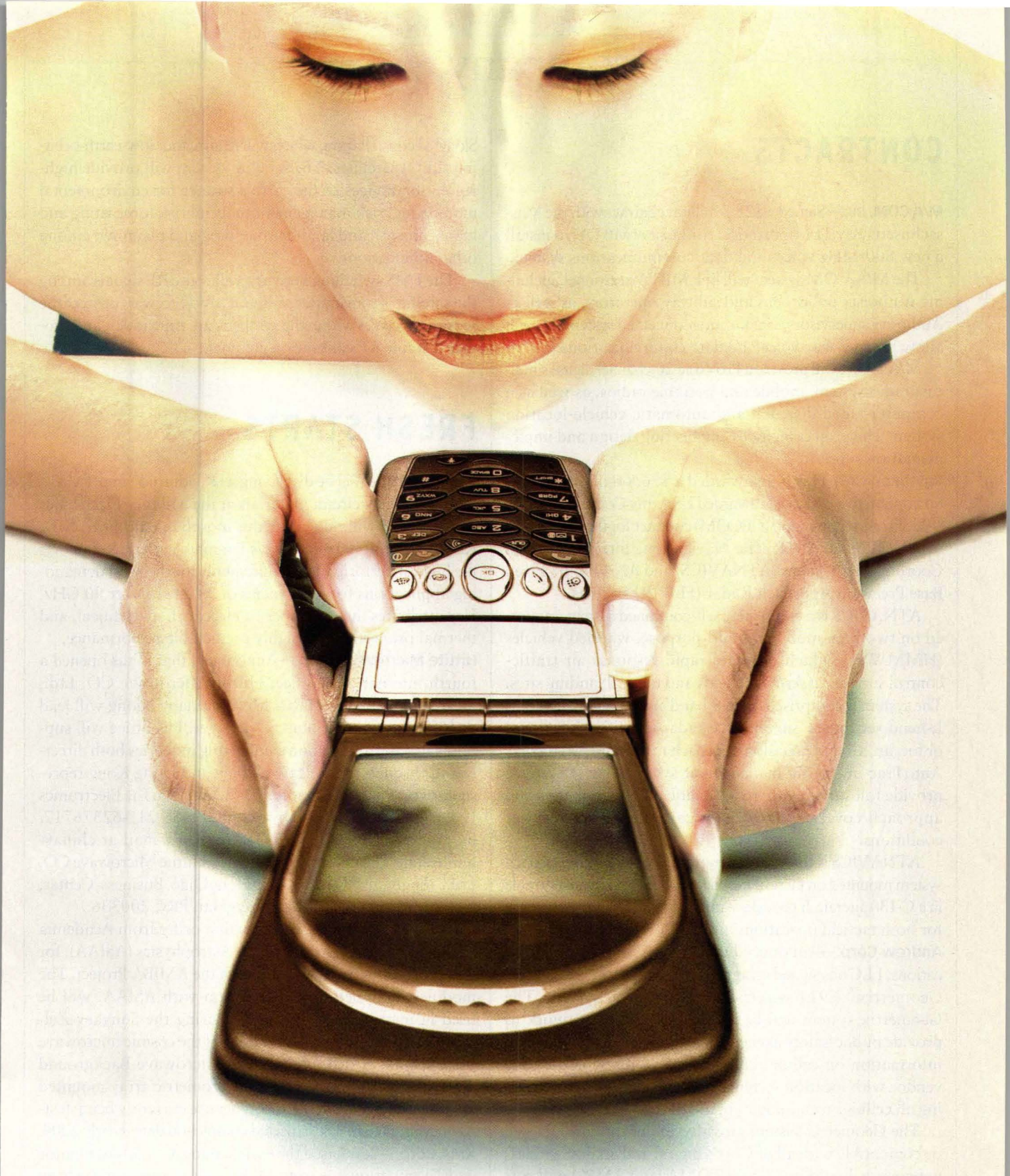
NORTHROP GRUMMAN CORP. reported income from continuing operations of $207 million, or $1.09 per share, compared with $181 million, or $1.52 per share, for the same period of 2002. Second-quarter 2003 earnings per share are based on weighted average diluted shares outstanding of 184.4 million versus 114.8 million for the second quarter of 2002. Sales for the 2003 second quarter increased to $6.6 billion from $4.2 billion for the same period of 2002.

The 2003 second-quarter results reflect contributions from the company's two new operating segments, Mission Systems and Space Technology, and double-digit growth in sales and operating margin at its Electronic Systems, Information Technology, and Integrated Systems segments.The results also include a $68 million pre-tax charge on Ships' commercial Polar Tanker program.

Ronald D. Sugar, Northrop Grumman's president and CEO, says, "We are very pleased with the excellent operating results of all our defense and government businesses, reflecting the strength and depth of the new Northrop Grumman. Both heritage and recently acquired companies contributed significantly to today's results. Despite the charge on the Polar Tanker program, we were able to deliver a very strong quarter, including solid cash flow, and to increase 2003 earnings per share guidance.

"We are optimistic about Northrop Grumman's future growth and our ability to capitalize on the Department of Defense's 21st century transformation agenda," continues Sugar. "From the production of the most sophisticated sensors to the integration of systems-of-systems—from undersea to cyberspace—Northrop Grumman is uniquely positioned to shape and support the network-centric warfare future envisioned by our customers."

Northrop Grumman expects 2003 sales to be approximately $25 to $26 billion. For 2004, sales are expected to be approximately $28 to $29 billion, with solid double-digit earnings per share growth, assuming that pension costs are the same as they were in 2003. MRF



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CONTRACTS

M/A COM, Inc.—Signed a $25.7 million contract with the Massachusetts Bay Transportation Authority (MBTA) to install a new 800-MHz voice- and data-communications system.

The M/A-COM system will link MBTA personnel, including Authority police, bus and subway operators, as well as Authority supervisors, via one interconnected system this will allow for two-way voice and data communications.

M/A-COM will provide a ProVoice 20-channel digital simulcast radio system, mobile and portable radios, as well as a computer-aided dispatch and automatic vehicle-location system. The project includes engineering design and implementation support.

Raytheon Co.—Has been awarded a $16.8 million production option to a previously awarded US Army Communications—Electronics Command (CECOM) contract for the production of AN/TPN-31 Air Traffic Navigation, Integration, and Coordination Systems (ATNAVICS) and AN/FPN-67 Fixed Base Precision Approach Radar (FBPAR) systems.

ATNAVICS is a completely self-contained system, mounted on two high-mobility, multi-purpose, wheeled vehicles (HMMWVs), which provides rapid-response air-traffic-control services at Army airfields and tactical landing sites. The system is comprised of an S-band air-surveillance radar, L-band secondary surveillance radar/identification friend or foe, an X-band precision approach radar, and Raytheon's AutoTrac air-traffic management system. These systems provide full surveillance to 25 nautical miles and precision approach coverage to 10 nautical miles in all weather conditions.

ATNAVICS is the only radar ground-controlled approach system mounted on tactical mobile vehicles that is transportable in a C-130 aircraft. It provides a rapid air-traffic-control response for both tactical operations and civil disasters.

Andrew Corp.—Announced that Corr Wireless Communications, LLC has signed an agreement to purchase an Andrew Geometrix® E911 wireless caller location system. The Geometrix system will be installed in Corr's network to provide public-safety agencies with accurate caller-location information on cellular calls to 911. Andrew is the only vendor with location systems in commercial service covering all cellular technologies in use in the US.

The Geometrix system provided under the contract will be compatible with all of Corr's digital and analog wireless network technologies (GSM, TDMA, and AMPS) and customer handsets.

EMS Technologies, Inc.—Has received a contract valued at $5.7 million from ALENIA SPAZIO to supply key switching technology for the COSMO SkyMed earth observation satellite mission set for launch in 2005.

EMS's Space & Technology/Atlanta division will manufacture and deliver space-qualified X-band ferrite switching networks and electronic power converters for the COSMO SkyMed constellation, which will feature four low-earth-orbiting (LEO) satellites. The satellite system will provide high-resolution images of the earth's surface for environmental monitoring, risk management (natural risk forecasting and management), and land-use mapping and planning, among other applications.

The EMS switching network will route RF signals among the satellite's transmitter, antenna, and receiver, protect the sensitive receiver within the synthetic aperture radar, and provide a stable RF calibration channel.

FRESH STARTS

Rogers Corp.—Will be displaying its RT/duroid® and TMM® high-frequency circuit materials at the Military Electronics Show, which will take place this month in Baltimore, MD. Rogers' traditional microwave laminate materials supports the highest performance requirements for the most demanding applications for frequencies of 3 GHz to over 90 GHz. Key attributes include superior electrical, mechanical, and thermal properties and highly predictable performance.

Hittite Microwave Corp.—Announced that it has opened a fourth international office, Hittite Microwave CO. Ltd., located in ShangHai, PRC. Mr. HuaLiang Xiong will lead the office as China Country Manager. His office will support sales and application engineering inqueries both directly and through Hittite's two China and Hong Kong representatives, Planet Technology Ltd. and WaiTat Electronics Ltd. He can be contacted by phone at (+86-21) -62376717, by fax at (+86-21) -62376716, or via e-mail at china@hittite.com. The new office address is: Hittite Microwave CO. Ltd., (ShangHai Office), 7T, HongQiao Business Center, No. 2272, HongQiao Rd., ShangHai, PRC 200336.

Marki Microwave—Received its first order from Academia Sinica, Institute of Astronomy & Astrophysics (ASIAA), for 4-lag correlator modules for use on the AMiBA Project. The modules, designed in collaboration with ASIAA, will be used in instrumentation for measuring the Sunyaev-Zeldovich effects and the Polarization of the cosmic microwave background. AMiBA (Array for Microwave Background Anisotrophy) consists of an interferometric array mounted on a steerable platform. Prototypes are currently being tested on Manua Loa. The expected completion date is early 2004.

XMA Corp.—Purchased the entire connectorized Attenuator and Termination line from M/A-COM in July and is setting up full manufacturing operation.

CSMC Technologies Corp.—Announced that it has closed a $67 million US first investment round with a consortium of international investors. The round was led by 3i, the global venture-capital/private-equity investor, and Crown Crystal Investments Ltd. (CCI), a company representing the interests of one of the largest technology-focused venture-capital management firms in Asia. MRF

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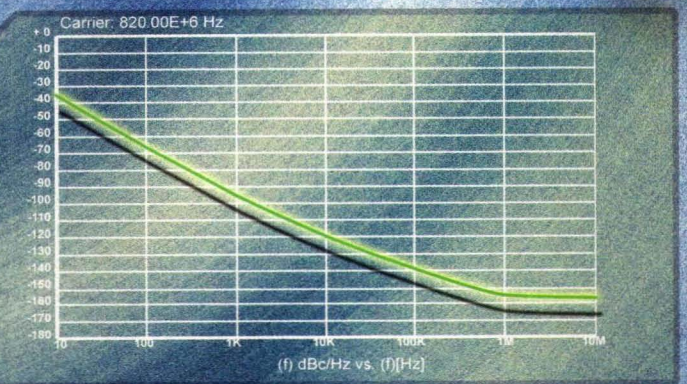

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REICHELDERFER

Reichelderfer Is Named As ITT Industries' President

ITT Industries, Cannon has tapped BRENDA L. REICHELDERFER for the position of president. Reichelderfer was previously president of the ITT Motion & Flow Control segment. She joined ITT Industries' predecessor company, ITT Corp., in 1982.

W.L. Gore & Associates—RUSSELL SHALLER to division manager for Gore's Electronic Products Division; formerly the general manager for Gore Photonics. Also, JOE GALLO to global sales manager for the Electronic Products Division; formerly business manager for Gore's wire and cable operation in the US.

Zetex—CRAIG BELL to product marketing manager in the Signal Management Group; formerly product manager for access products at Fujitsu Microelectronics GmbH. Also, SIMON RAMSDALE to the position of product marketing manager in the Signal Management Group; formerly strategic marketing and applications manager for high-speed amplifiers at Texas Instruments.

EMS Technologies, Inc.—ALAN L. HAASE to senior vice president and general manager for EMS Space & Technology/Montreal Division; formerly president, CEO, and chief strategy officer for SkyCross, Inc. Also, GERALD S. BUSH to special assistant to the CEO; formerly president and general manager of the Space & Technology Group.

Times Microwave—PAUL TUSINI to global accounts manager; formerly employed with Volex RF Technologies.

Indigo Systems Corp.—STEPHEN P. KAUFMAN to the board of directors; continues as senior lecturer of Business Administration at the Harvard Business School.

UT-Battelle—DR. JEFF WADSWORTH to director of the Oak Ridge National Laboratory (ORNL); formerly senior leader at the Lawrence Livermore National Laboratory.

Broadcom Corp.—ANDREW J. PEASE to vice president of worldwide sales; formerly vice president of sales at Syntricity, Inc.

Andrew Corp.—MARTY R. KITTRELL to CFO; formerly vice president of strategic planning. Also, GREGORY F. MARUSZAK to chief compliance officer; formerly vice president for finance. In addition, DANIEL J. HARTNETT to vice president of tax; formerly tax director.

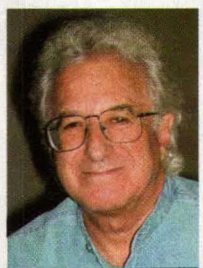
NewSouth Communications—STEPHEN SHOEMAKER to CFO; formerly CFO at Group Telecom (GT).

Powerhouse Technologies Group, Inc.—JOSHUA FELLER to the position of president and COO of Powerhouse's wholly owned subsidiary, FWD Solutions, Inc.; formerly vice president of franchise operations and COO at Computerland Corp.

Vishay Intertechnology, Inc.—GLYNDWR SMITH to executive vice president for market intelligence; remains as assistant to the CEO as well as chairman of the board of Siliconix, Inc., an 80.4-percent-owned subsidiary of Vishay.

Integra Technologies, Inc.—JIM CURTIS to the position of director of sales and marketing; formerly principal engineer at Powerwave.


CURTIS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Applied Wave Research, Inc. (AWR)—JAMES E. SOLOMON to the board of directors; formerly president and CEO at Cadence Design Systems. MRF

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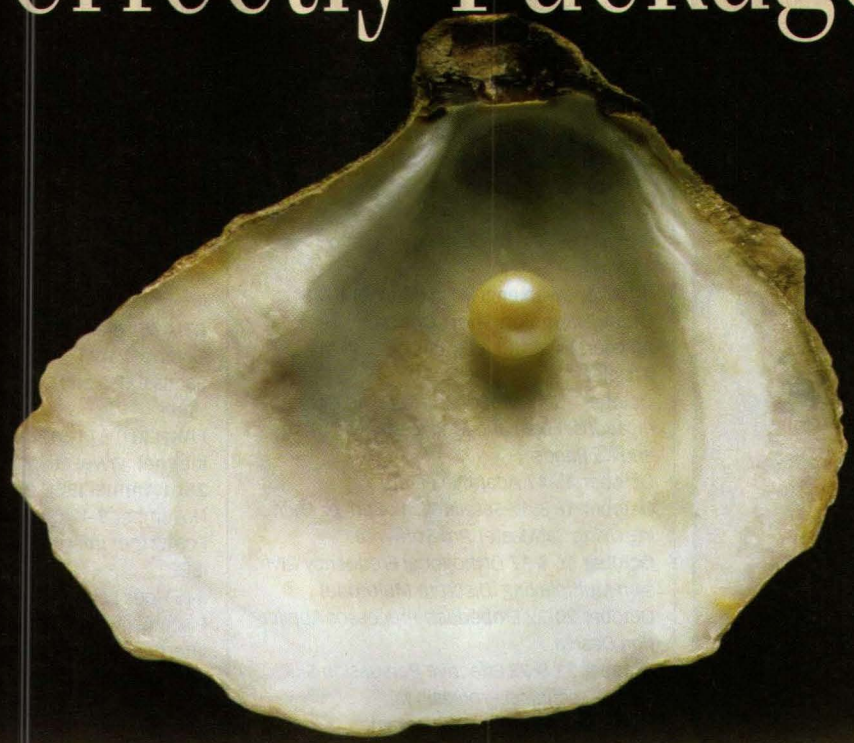

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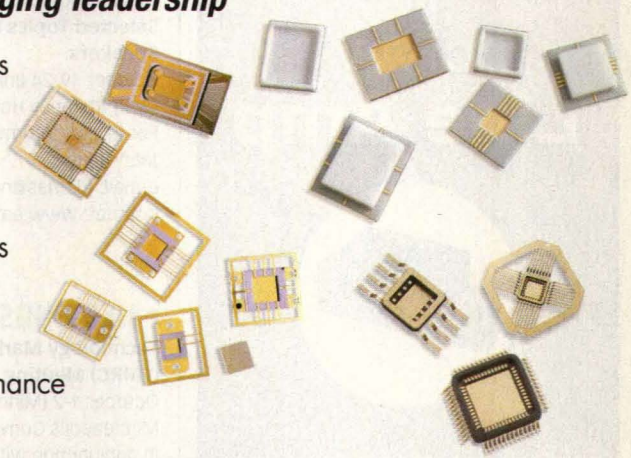

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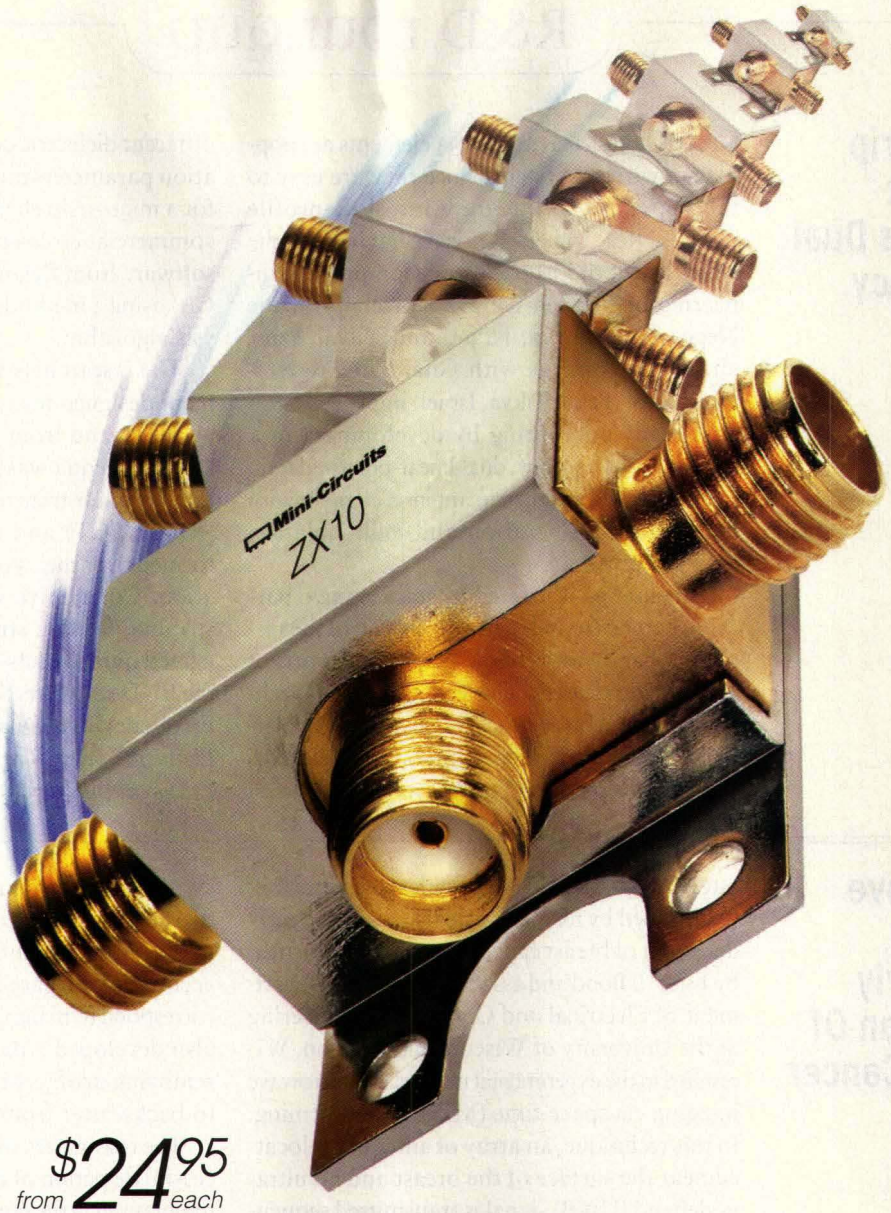

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ZX10-2-42	1.9-4.2	23	0.2	34.95
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Microstrip Element Features Dual Frequency

MICROSTRIP PATCH ANTENNA elements are popular in wireless systems since they are easy to fabricate and to integrate into low-profile designs. Researchers Reuven Shavit from the Department of Electrical and Computer Engineering of the Ben-Gurion University of the Negev (Beer Sheva, Israel) and Yuval Tzur, and Danny Spirtus with Gilat Satellite Networks Ltd. (Petah Tikva, Israel) improved upon an already good thing by developing a new type of dual-frequency, dual-linear-polarized multilayer stacked microstrip antenna element with wide band of operation and high isolation between ports.

An antenna is formed by stacking two parasitic patches to independently control the frequency bandwidths of the two feeding ports of a microstrip element. The feeding element mechanism is based on aperture coupling for one polarization and direct feeding for the orthogonal polarization. This results in a multilayer structure with different dielectric constants. The critical radiation parameters and currents were computed for a microstrip element model using the IE3D commercial electromagnetic (EM) simulation software from Zeland Software, Inc. (Fremont, CA) using a method-of-moments (MoM) analysis algorithm.

The researchers fabricated an antenna element designed for use from 14.0 to 14.5 GHz at port 1 and from 10.9 to 12.7 GHz at port 2. The antenna was made on RO4003 flexible dielectric substrate material from Rogers Corp. (Rogers, CT) and measurements were performed over the two frequency ranges of operation. Conductive viaholes were used in the stripline feeding structure. Measured results agreed quite closely with calculations made by the IE3D software. See "Design of a New Dual-Frequency and Dual-Polarization Microstrip Element," *IEEE Transactions on Antennas and Propagation,* July 2003, Vol. 51, No. 7, p. 1443.

Microwave Imaging Aids Early Detection Of Breast Cancer

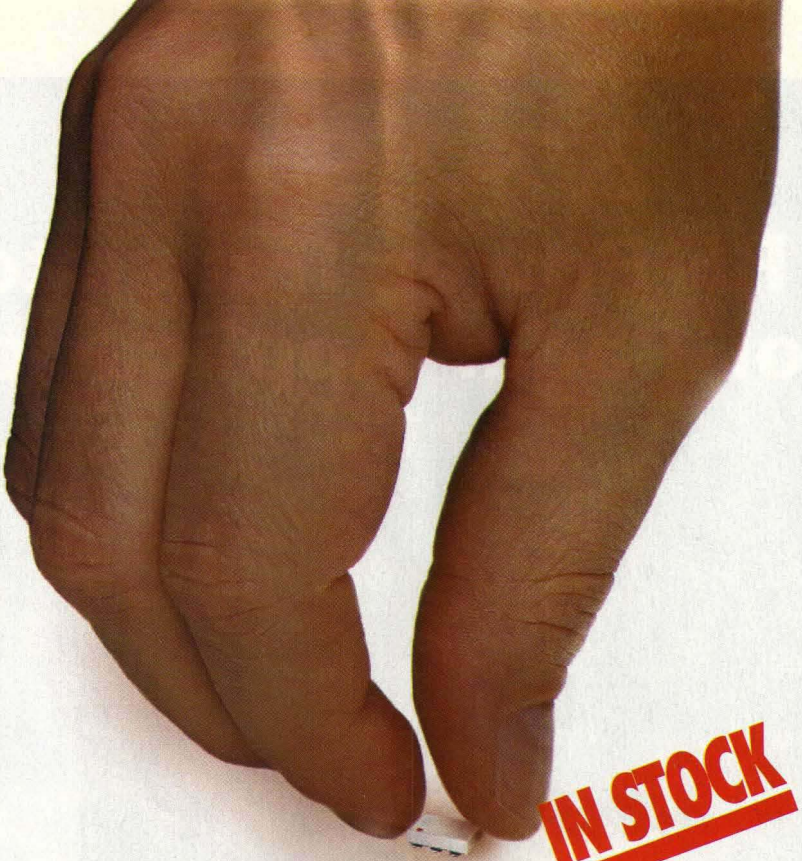
MICROWAVE IMAGING provides the information needed by medical professions for the early detection of breast cancer. Research performed by Essex J. Bond and associates from the Department of Electrical and Computer Engineering at the University of Wisconsin (Madison, WI) resulted in the experimental method for microwave imaging via space-time (MIST) beamforming. In this technique, an array of antennas is located near the surface of the breast and an ultra-wideband (UWB) signal is transmitted sequentially from each antenna. The received backscattered signals are passed through a space-time beamformer that is designed to image backscattered signals as a function of location. The beamformer spatially focuses the backscattered signals to discriminate against clutter and noise while compensating for frequency-dependent propagation effects. Because of the differences in dielectric constant between normal and malignant tissue, localized regions accounting for large backscatter energy levels correspond to malignant tumors. The researchers also developed a data-adaptive algorithm for removing artifacts in the received signals due to backscatter from the skin-breast interface.

The researchers were able to demonstrate successful detection of millimeter-sized malignant tumors even in the presence of dense healthy breast tissue,, with the aid of the data-adaptive algorithm for suppression of clutter and noise from surrounding biological masses and tissues. See "Microwave Imaging via Space-Time Beamforming for Early Detection of Breast Cancer," *IEEE Transactions on Antennas and Propagation,* August 2003, Vol. 51, No. 8, p. 1690.

Measure ADC Noise By Cross Correlation

DEEP EMBEDDED INTERCONNECTS for low-temperature-cofired-ceramic (LTCC) clear the way for fabrication of circuits on thick LTCC substrates and the development of highly integrated buried passive components in multilayer circuit designs. J.J. Yu, B.T. Tan, and S.T. Chew of the DSO National Laboratories in Singapore developed LTCC broadband deep embedded interconnects (DEI) for use with an embedded bandpass filter. Their design is based on low-cost 951 tape from Dupont and achieves low-loss performance through 20 GHz. Although designed nominally for X-band, the tape is suited for applications through Ku-band.

The researchers designed and fabricated a 14-layer LTCC structure to demonstrate the process, creating a three-pole broadside-coupled bandpass filter using stripline stepped-impedance resonators. The filter suffered only 2.2-dB loss at 16.4 GHz. See "LTCC Broadband Deep Embedded Interconnects (DEI) With Application For Embedded Bandpass Filter," *Microwave and Optical Technology Letters,* August 5, 2003, Vol. 38, No. 3, p. 179.



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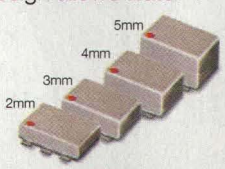

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DESIGN

Reviewing SDARS Antenna Requirements

Several conflicting requirements, such as achieving two separate high-gain antenna patterns within a single compact module, increase the challenge of designing SDARS antennas.

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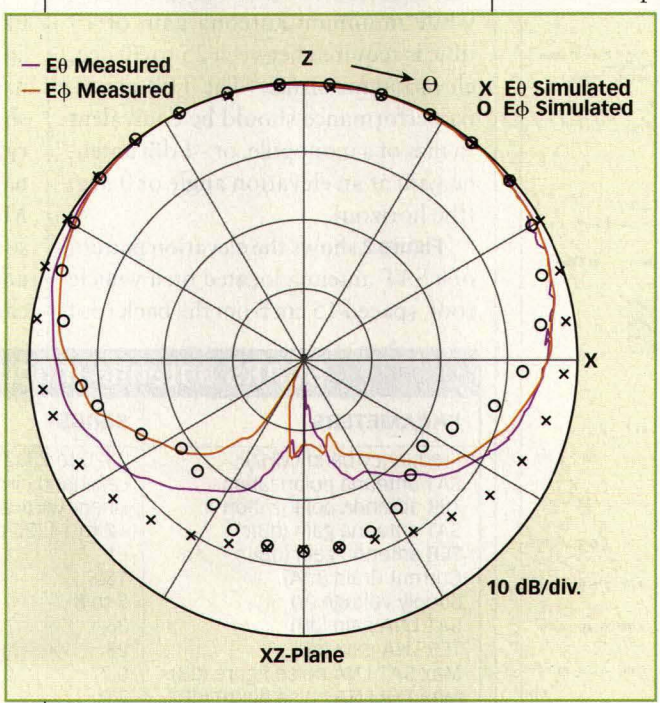
Automotive satellite radios, specifically the Satellite Digital Audio Radio System (SDARS), place stringent requirements on the receiving antenna. SDARS employs a dual-transmitter broadcast format in which signals are sent from both satellite-based and terrestrial transmitters. The satellite transmission cover most areas, but are complemented by terrestrial transmitters when satellite coverage is blocked (such as by tall buildings in urban areas). Examples of the SDARS include XM Satellite radio and SIRIUS Satellite Radio in the US, providing customers with as many as 100 channels of MP3-quality digital radio service. Antennas for SDARS must be able to handle both types of transmissions with optimal receive performance.



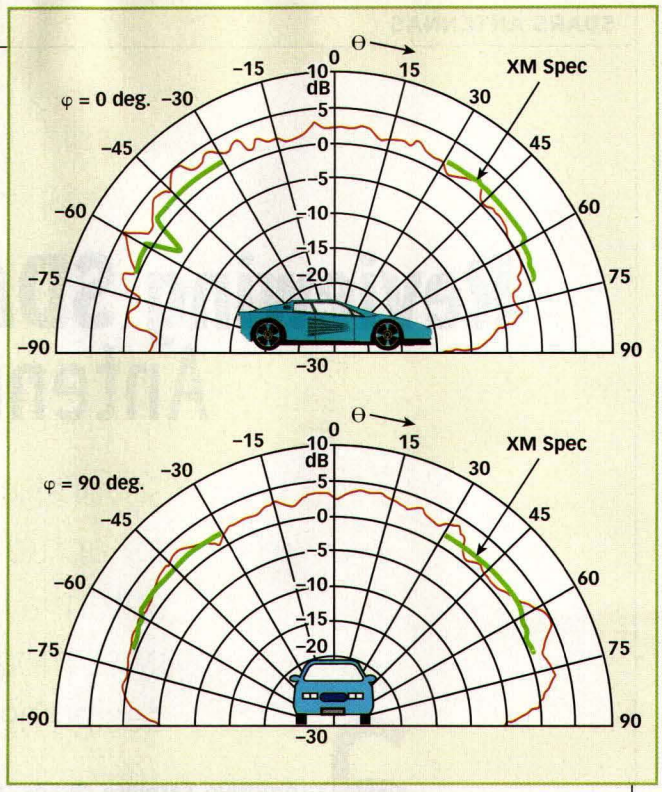
1. This SAT antennas elevation pattern was measured with the antenna on the center of 1-m ground plane.

Antenna modules for SDARS feature low-noise amplifiers (LNAs) and passive elements that receive low-power satellite signals and terrestrial signals. Currently, SDARS antennas are dual-arm antennas, consisting of two separate antennas, one optimized for terrestrial (TER) signal reception and the other optimized for satellite (SAT) signal reception. The TER element is typically a monopole, while the SAT element is a circularly polarized structure. Due to the requirements for extremely low noise figures, the LNAs are located directly below

the passive antennas. The separate outputs of the two LNAs is connected to RF cables typically 15 to 20 feet in length; the cables are terminated in SMB connectors to interface with the SDARS radio equipment.

The basic electrical performance of SDARS antenna modules is summarized in the table. The SAT antenna employs left-hand circular polarization while the TER uses linear polarization. Type-approval antenna testing requires that the mobile antenna module be mounted at the center of a 1.0-m-diameter circular ground plane. **Figure 1** shows a typical elevation pattern in two planes of an SAT antenna placed at the center of such a ground plane.[1] Minimum antenna gain of +2 dBic is required for elevation angles between 20 to 60 deg. for XM, while minimum antenna gain of +3 dBic is required between 25 to 90 deg. elevation for Sirius.[2] The TER antenna performance should be equivalent to that of a monopole, or –1 dBi antenna gain at an elevation angle of 0 deg. (the horizon).

Figure 2 shows the elevation pattern of a SAT antenna located on a vehicle roof, spaced 15 cm from the back roof edge.[2] The pattern curves are not as smooth as the ground plane curves of Fig. 1 due to asymmetries. While on a vehicle, ideally the antenna elements must be positioned in a substantially unobstructed view of the satellites. The ideal location of a mobile antenna module is on the vehicle roof. Both SAT and TER elements of roof-mount antennas require a minimum of six inches from sheet metal edge to provide satisfactory antenna performance.[3] Other antenna modules such as those for Advanced Mobile Phone Service (AMPS), personal communications services (PCS), and Global Positioning System (GPS), can be incorporated with an SDARS



2. This SAT antenna elevation pattern was measured with the antenna located on a vehicle roof, 15 cm from the roof edge.[2]

SDARS antenna-module performance

PARAMETERS	SIRIUS	XM
Frequency band (MHz)	2320 to 2332.5	2332.5 to 2345
SAT antenna polarization	Left-hand circular	Left-hand circular
TER antenna polarization	Linear vertical	Linear vertical
SAT antenna gain (dBic)*	+2 to +4 (25 to 90 deg.)	+2 to +4 (20 to 60 deg.)
TER antenna gain (dBi)*	–1	–1
Current drain (mA)	150	90 to 110
Supply voltage (V)	5 to 8	4 to 5
SAT LNA gain (dB)	36	32
TER LNA gain (dB)	28	30
Max SAT LNA noise figure (dB)	0.7	0.7 to 1.2
Max TER LNA noise figure (dB)	2.0	1.5
Filter attenuation at ±250 MHz	35 dB	25 to 35 dB

Note: The antenna was placed on the center of a 1-m-diameter ground plane.

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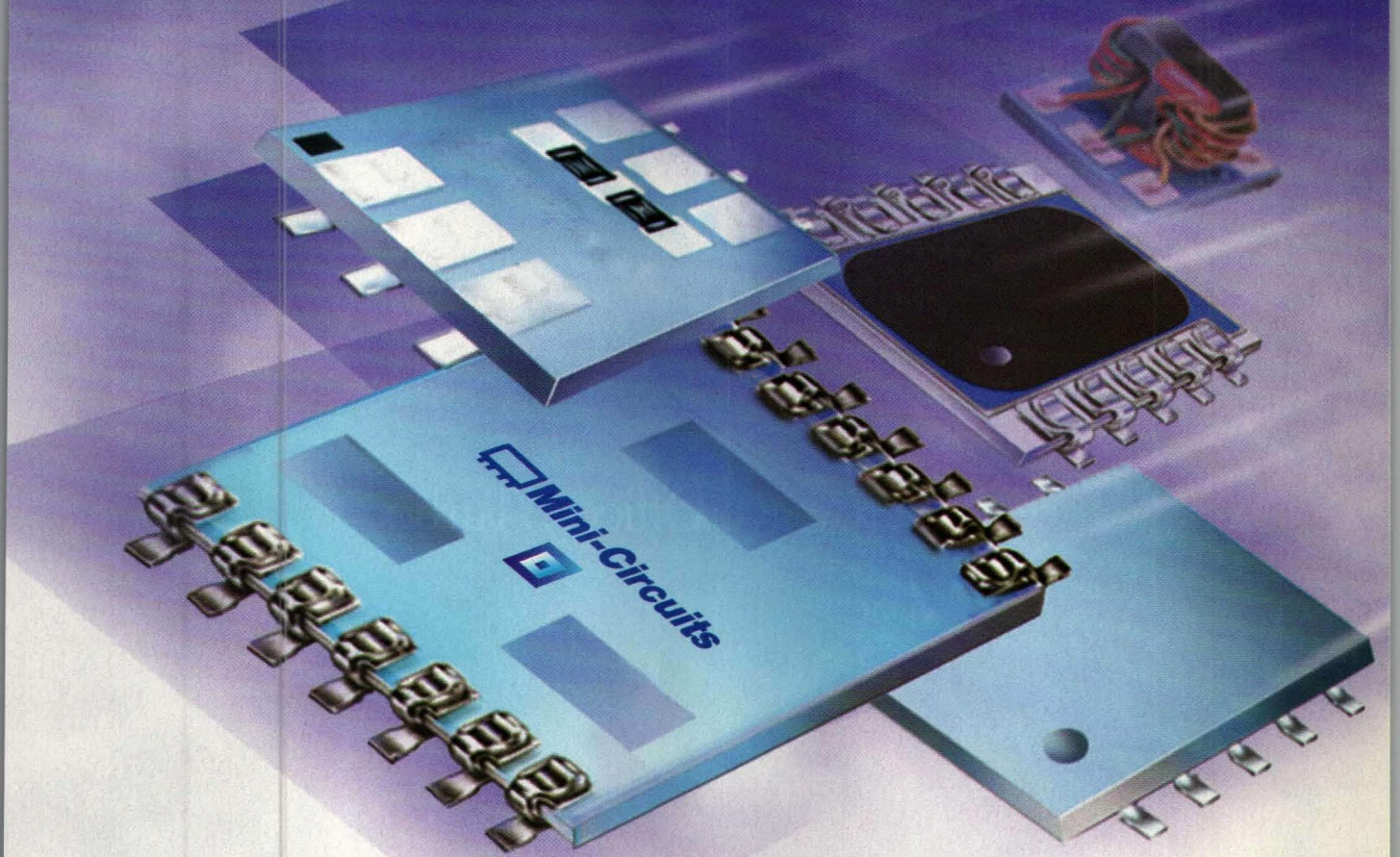

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2	90	QCN	5	425-2700	17-30	0.4-0.6	4-13	3.95
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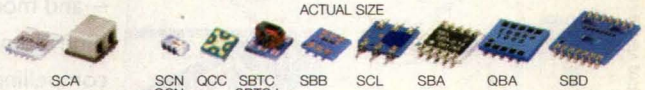

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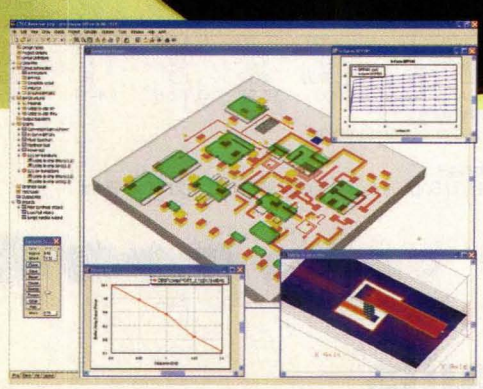

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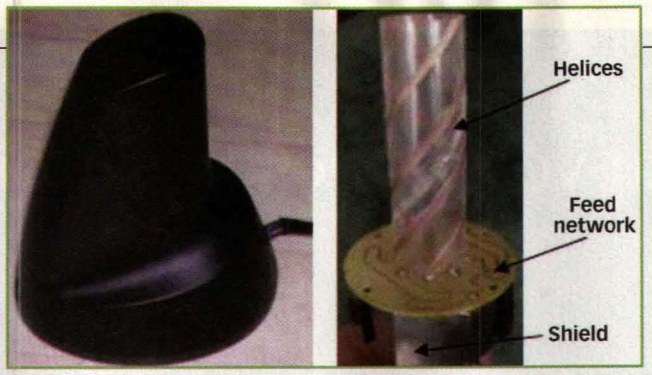
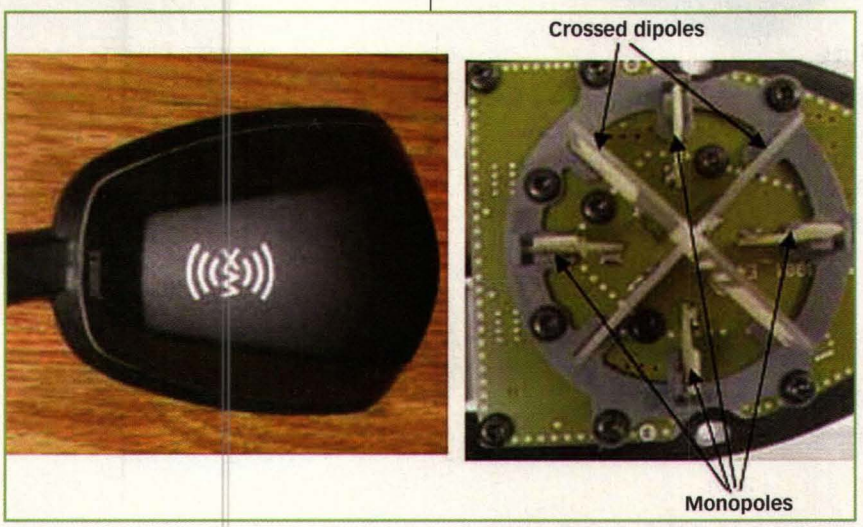


3. This design is a combination of a quadrifilar antenna and a monopole structure.

antenna in a common housing as long as the antennas do not interfere with each other. (For example, enough isolation should be provided between the PCS band at 1920 to 1990 MHz and the SDARS band at 2320 to 2345 MHz.)

Figure 3 shows a standard quadrifilar SAT antenna with a helix monopole TER structure located inside the quadrifilar antenna. The quadrifilar helix antenna consists of four helices spaced equally and circumferentially on a cylinder. The four helices are etched on a flexible substrate and wrapped in a cylindrical fashion. From much research,[4-8] it is known that quadrifilar antenna performance is unaffected by the presence of the monopole inside. A feed network printed on a low-loss flexible substrate, along with the helix winding direction, helps achieve the left-hand circular polarization. To improve the return loss and radiation characteristics of the monopole antenna, the shield height below the antennas is much higher than that of a standard shield (typically 5 mm). This arrangement yields excellent antenna performance, nearly equal to that of a typical monopole antenna. The height of the antenna including the housing is approximately 95 mm.

Figure 4 shows a crossed dipole/monopole array combination. The assembly consists of a crossed dipole structure for receiving the circularly polarized satellite signals and an array of four monopoles for receiving linearly polarized terrestrial signals.[9] The dipoles are etched on a low-loss substrate. While crossed dipoles have been around for several years and used extensively in mobile SAT communications,[10,11] the novelty of this design is in the way the monopole array is arranged symmetrically about the cross dipoles. This symmetrical configuration yields good performance for both the SAT and TER antennas. Each monopole is positioned within each quadrant of the cross dipole. Each monopole is approximately 0.25 wavelengths in length. The four monopoles are connected to a standard corporate feed network. The two crossed dipoles are connected to a 90-deg. equal-power feed network etched on a low-loss substrate. This configuration yields the circular polarization required for SDARS. The SAT antenna provides



4. This XM antenna features a crossed dipole/monopole array combination.

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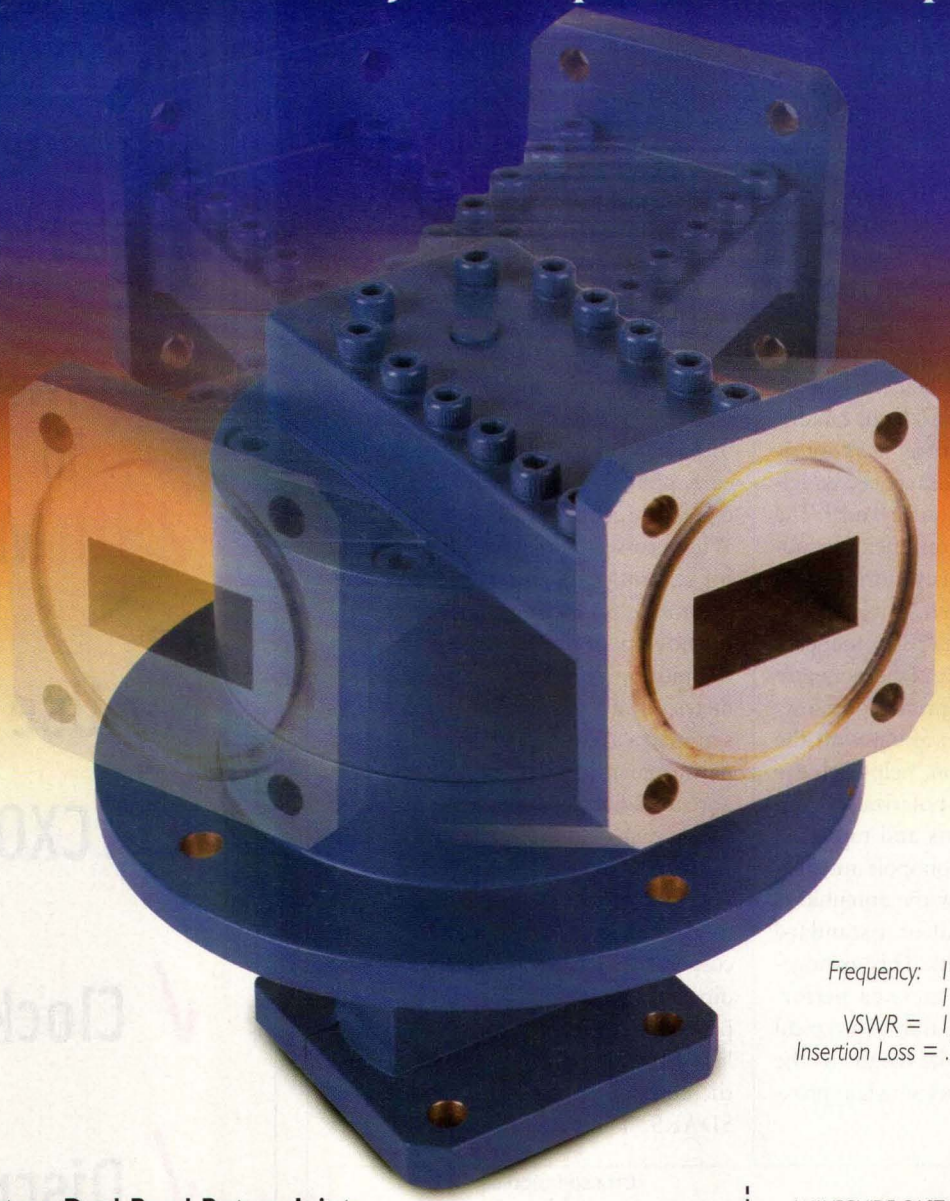

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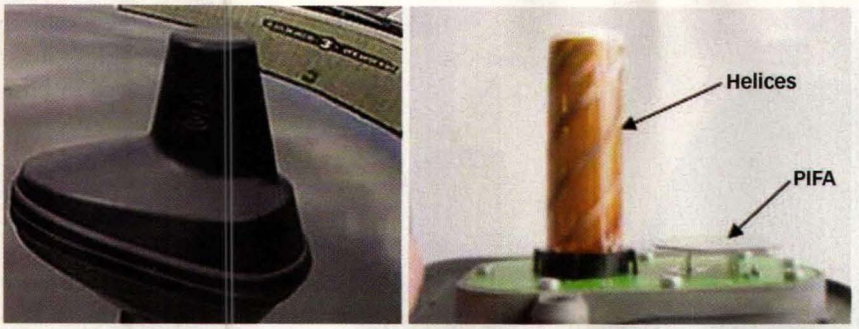


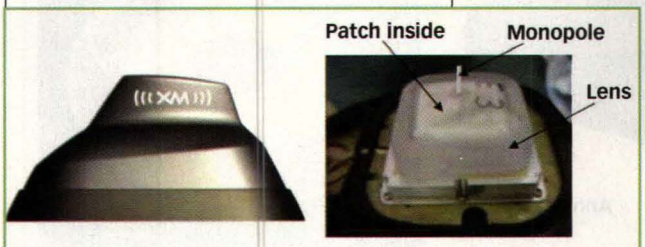
5. This antenna design is a combination of quadrifilar and PIFA structures.

excellent performance for elevation angles of 45 deg. or higher. The height of the antenna including the housing is approximately 40 mm.

Figure 5 shows that the SAT element of the quadrifilar/PIFA combination is a "folded" low-profile quadrifilar antenna while the TER element is a planar inverted-F antenna (PIFA).[12,13] The "folded" quadrifilar antenna is essentially a standard quadrifilar antenna, where the helices in the top section are folded or bent back resulting in a shorter antenna. The helices are etched on a flexible substrate and then wrapped in a cylindrical fashion. The width of each line is 2 mm and each helix is matched to 50 Ω and connected to a miniature surface-mount feed network.[14] The helix antenna height is 6 cm. The SAT antenna provides good performance between elevation angles 20 and 60 deg. However, the TER antenna radiation pattern exhibits a valley due to blockage by the quadrifilar antenna. The height of the antenna including the housing is approximately 70 mm.

Figure 6 shows this configuration's lens-loaded ceramic patch SAT antenna. The TER element is a quarter-wave monopole located in the center of the antenna structure and extends from the base through a hole in the patch. The lens helps increase the patch gain at low elevation angles (20 to 30 deg.) by increasing the antenna beamwidth. However, the antenna gain at high-elevation angles is reduced compared to a patch with no lens. Care must be taken in the placement of the monopole so that it does not interfere with the radiation pattern of the patch antenna, especially when high-dielectric-constant ceramic materials are used. The height of the antenna including the housing is approximately 40 mm.

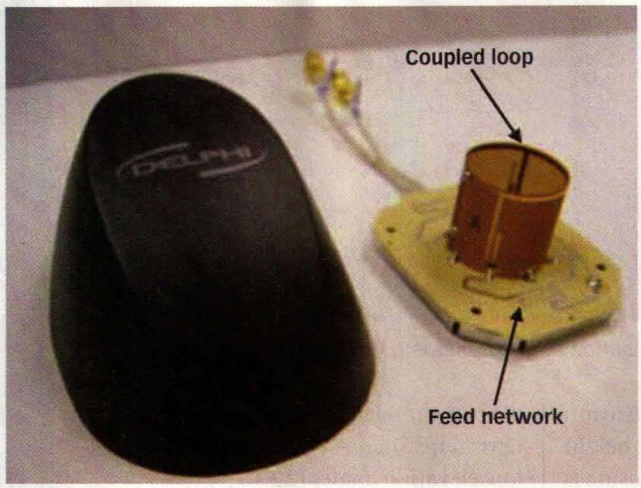
Of the various antenna SDARS configurations discussed, the coupled loop/monopole combination is the most popular **(Fig. 7)**. It is sold along with the popular XM Delphi SkyFi™ receiver. The SAT element is a coupled-loop antenna with perimeter length of approximately one-half wavelength. The TER element is a helix monopole located inside the SAT antenna without affecting the SAT design's performance. A feed network printed on a low-loss substrate helps achieve the left-hand circular polarization. It is similar to the feed network used on the quadrifilar/monopole combination design (Fig. 3). This arrangement yields good performance for both SAT and TER antennas in that the TER radiation pattern presents no asymmetries. The height of the antenna including the housing is approximately 30 mm.



6. This patch antenna features a lens and monopole structure combination.

Figure 8 shows an annular microstrip antenna consisting of a full-wavelength loop etched on a low-loss

substrate. This type of patch antenna operates in TM_{21} mode and produces a conical radiation pattern. It yields good performance for elevation angles between 20 and 60 deg. but poor performance at higher angles (60 to 90 deg.), with a null at the zenith (90 deg.). For this reason, it is not suitable for Sirius applications. The TER antenna is a top-loaded monopole located at the center of the annular patch and at the same height as the patch. The SAT antenna performance is unaffected by the presence of the monopole. The TER radiation pattern is similar to that of a standard quarter-wave monopole with slightly less gain. The height of the antenna including the housing is approximately 15 mm and it is the lowest-profile XM antenna.



7. This Delphi antenna is a combination of a coupled loop and monopole structures.

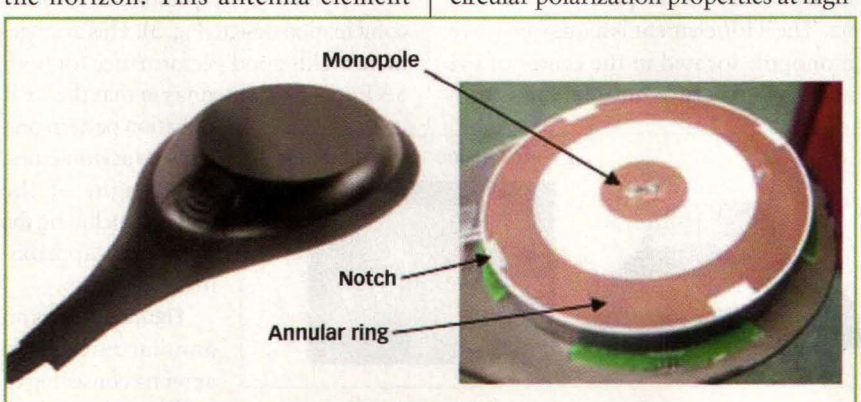
For applications where no ground plane exists, mast or ground-independent antennas are needed. These antennas are mounted on sedan or sport-utility-vehicle (SUV) window glass or on the mirrors of long-haul trucks. A quadrifilar helix antenna is a typical mast-type ground-independent SAT configuration for SDARS. In such a configuration, the four helices and feed network are printed on a low-loss flexible substrate and wrapped around a cylindrical tube **(Fig. 9a)**.

The TER antenna should also be designed to be ground-independent. A natural choice for this element would be a dipole. The first SDARS mast antenna shipped was the TRK SR1 **(Fig. 9b)**.[15] It is a combination SAT and TER antenna comprising a quadrifilar helix antenna and a tubular dipole.[16] The SAT coaxial cable runs substantially concentrically through the dipole without affecting the dipole's radiation characteristics. This arrangement effectively reduces coupling between the two elements and yields good performance for both antennas. The TRK SR1 design is unique in that both dc power and RF energy are transferred from the interior of the vehicle glass to the exterior surface. The coupling scheme utilizes two pairs of RF couplers (SAT and TER), and a pair of large coils which are part of the DC power (bias) circuitry. The LNAs are placed on the exterior glass surface, underneath the antennas, to maintain the low-noise-figure requirements. Technical challenges to this arrangement include oscillation due to the undesired coupling between the antennas, couplers, and LNA outputs, and interference on the AM radio caused by the DC transferring circuitry. These problems are avoided by correct LNA design, filtering, and proper antenna installation.

In an alternate implementation from the design of Fig. 9b, the dipole is replaced by a monopole that is printed on the same flexible substrate as the feed network. In this case, the monopole average gain is approximately –1 dBi at the horizon. This antenna element arrangement yields a shorter combination on-glass mast antenna and is used in both the TRK SR1X (a shorter version of the TRK SR1) and the TRK XM11 antennas **(Fig. 9c)**.[15]

More recently, on-glass XM mast antennas have been introduced, incorporating RF coupling only (models XM8000F in **Fig. 9d** and XM8100F).[15] These configurations utilize low-loss RF couplers for both SAT and TER elements. The SAT coupler loss is 0.5 dB, and this scheme avoids the potential oscillation and AM interference issues of the TRK SR1 and SR1X models. The trade-off, however, is an increase in noise figure of approximately 0.7 dB for SAT (0.5 dB coupler loss + 0.2 dB cable loss). The TER coupler is physically smaller than the SAT coupler, resulting in a 1 dB loss. The TER antenna for this design is a folded dipole located underneath the SAT antenna. Long-haul truck, recreational vehicle (RV), and marine antennas are mast antennas similar to the quad/dipole or quad/monopole combinations.[15]

To reduce the cost of the various antenna modules presented here, there is a need for developing single-arm antennas. These antennas consist of a single passive element and a single LNA configured such that good reception of both TER and SAT signals is achievable. Such modules exhibit vertical polarization properties along the horizon and circular polarization properties at high-



8. This antenna is a combination of a TM_{21} mode annular patch and a monopole.

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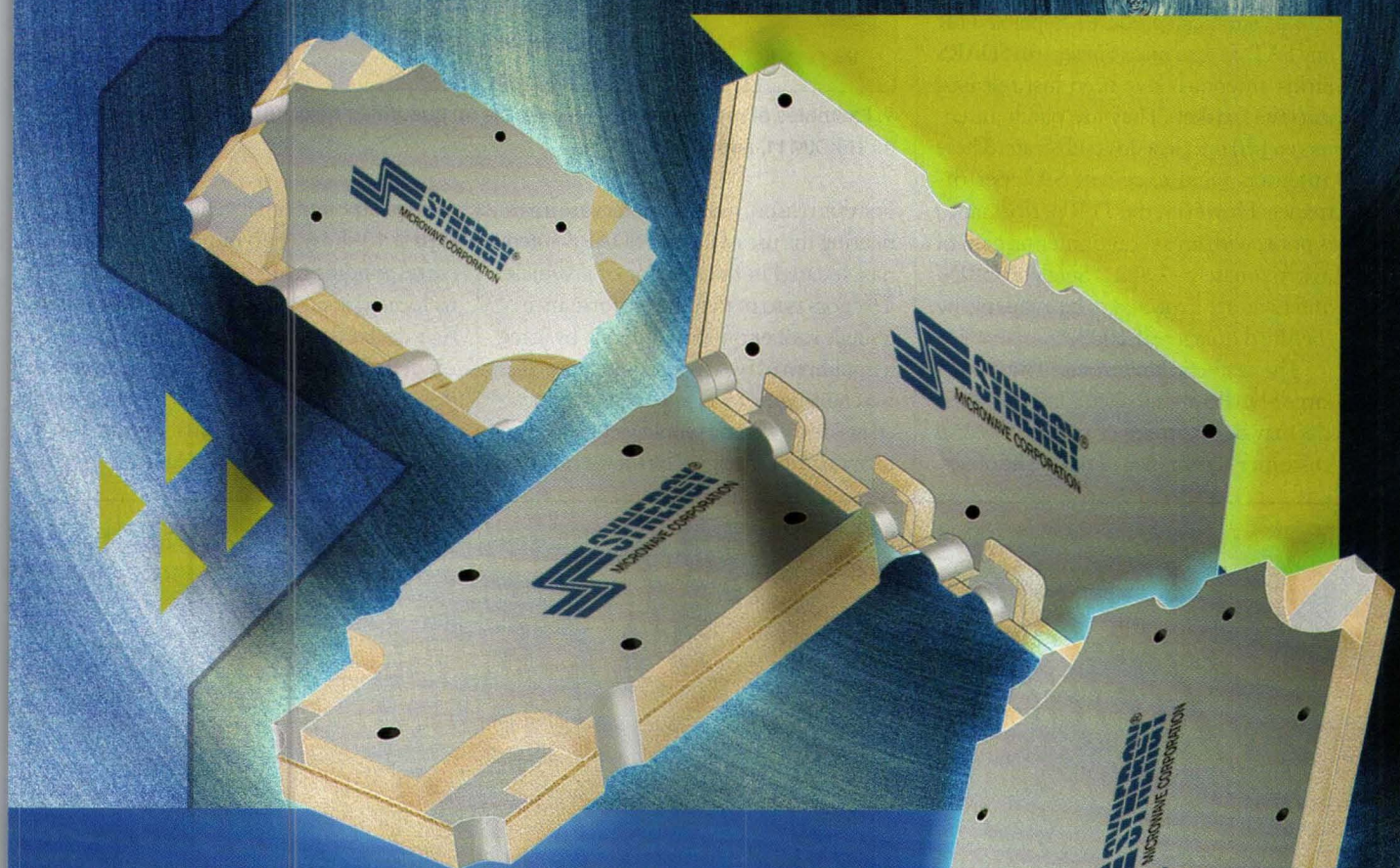

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er elevation angles. Currently, the vast majority of all SDARS receivers have two antenna inputs (TER and SAT). Single-arm antennas can be equipped with an RF splitter in order to be connected to dual-input receivers. A good candidate for single-arm antennas is a microstrip patch antenna etched on a low-loss ceramic or substrate. The right choice of ceramic or substrate can produce acceptable TER and SAT performance. Single-arm SDARS Sirius antennas have been just released into the market. They are patch antennas etched on a low-loss substrate. These antennas yield excellent SAT performance. However, the TER performance is poor, with an average antenna gain of approximately –7 dBi.[17] Single-arm XM antennas are expected to be available by the third quarter of 2003.

The aesthetic limitations of mounting large SDARS antenna structures on vehicles may be in part responsible for the slow customer acceptance of this technology.

9. Examples of mast antennas include the (a) quadrifilar helix, (b) TRK SR1 antenna, (c) TRK XM11, and (d) XM8000F.

For this reason, manufacturers are investigating the use of hidden SDARS antennas, located in the interior of a vehicle. The goal is to match the performance of a single roof or on-glass antenna by using a minimum of two hidden antennas. This is a challenging task, since antennas located inside the vehicle would yield poor performance due to signal blockage from the roof, pillars, and other vehicle structures. **Figure 10** shows two radiation patterns corresponding to an SDARS SAT antenna located inside a sedan (front dash and rear deck lid) for the elevation angle of 25 deg. By itself, neither of the radiation patterns is acceptable. However, when the two patterns are combined through a receiver diversity algorithm, the

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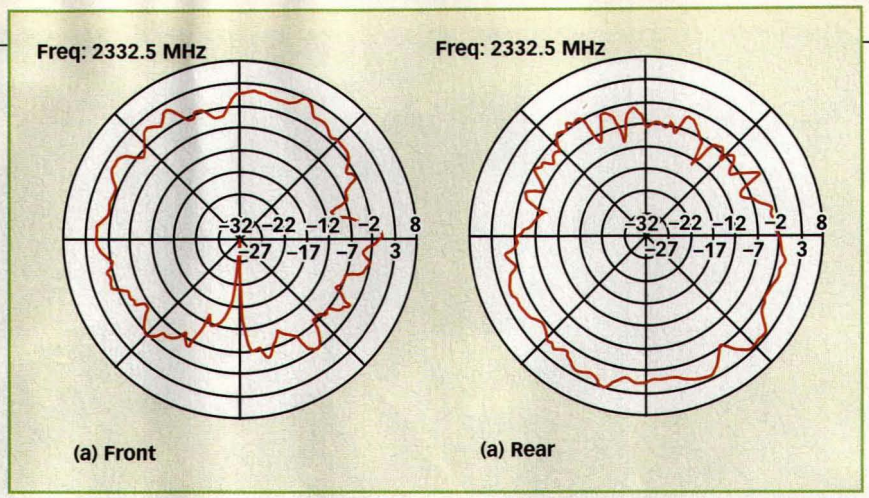
resulting radiation pattern can be significantly improved. A potential antenna choice for this application is a patch antenna. A pair of patch antennas can be used, one placed in the front and the other in the rear of the vehicle. A perceived disadvantage of implementing hidden antennas is the cost increase associated with each additional antenna module: the antenna element, LNA, cable, and connector. MRF



10. These radiation patterns were measured for an SAT antenna inside a sedan (elevation angle of 25 deg.): (a) at the front dashboard and (b) at the rear deck lid.

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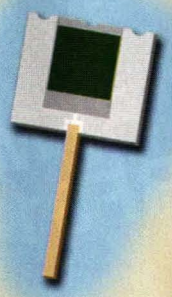

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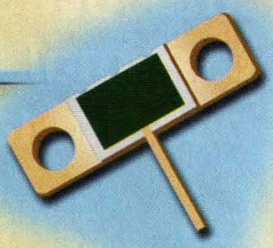

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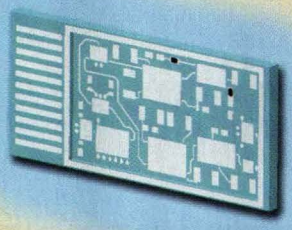

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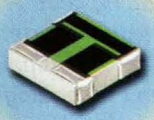

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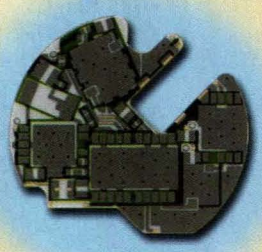

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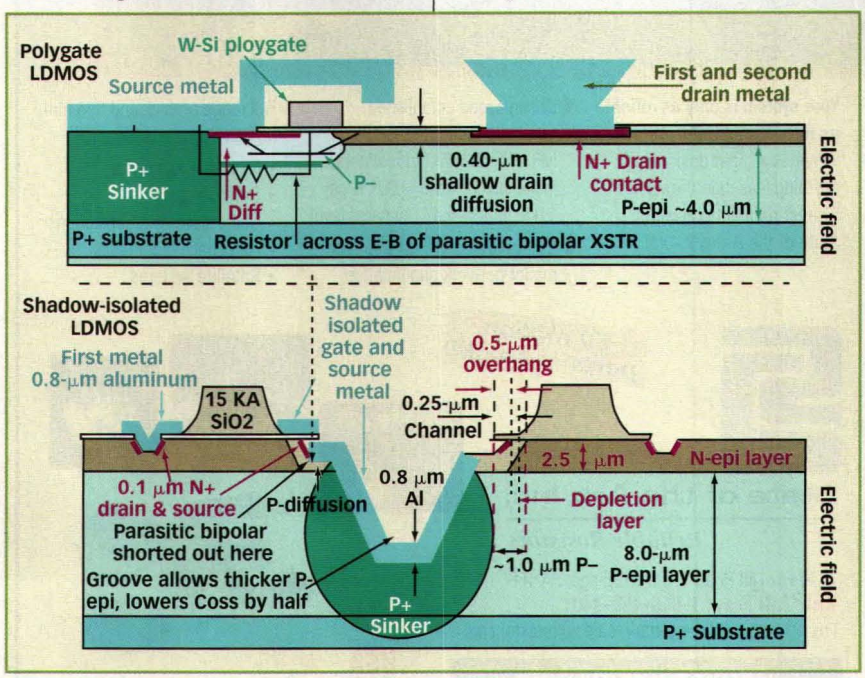
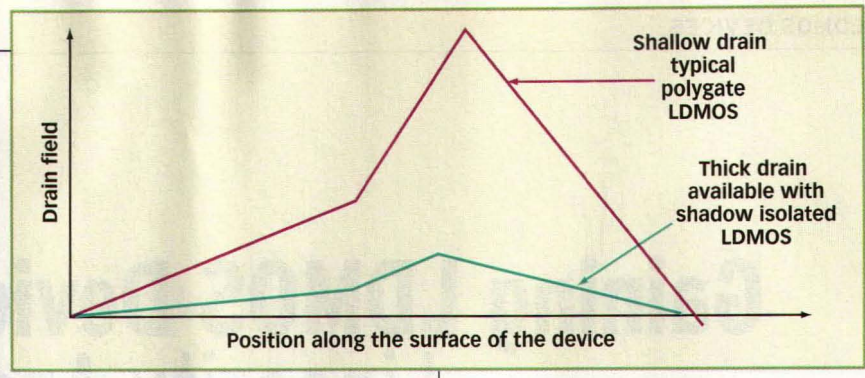
Power lateral diffused metal-oxide-semiconductor (LDMOS) transistors, popularly used in linear high-power amplifiers (HPAs) for cellular base stations, are not without their linearity and stability problems. In addition to long-term threshold drift, stability problems have recently surfaced which include short-term "memory" problems requiring complex and expensive corrective circuitry. To examine these problems more closely, the "hot-electron" problem inherent in all current production LDMOS devices will be investigated and correlated with both short- and long-term device characteristics related to hot electrons. This article will also explore a novel design approach that not only eliminates the hot-electron problem completely, but may also allow a dramatic improvement in device linearity.



1. A conventional polygate LDMOS device (top) is compared here to a shadow-isolated LDMOS device (bottom).

The LDMOS threshold drift problem has been discussed for many years. Most of the focus has been on hot electron injection into the gate oxide, causing a drift in the threshold voltage of the LDMOS device,[1-3] changing the idling current, (I_{dq}), with time. This, in turn, affects the gain, output power, and linearity of the circuit. Recent reports have documented short-term "memory" effects that have proven annoying to RF circuit designers.[4,5] It appears that these short-term effects can be controlled (to some extent) by including a capacitor network in the bias circuit, reducing the nonlinear characteristics of the amplifier. As will be shown, these short-term effects are most likely the result of current/voltage distortion in the transfer characteristics of the device, brought about by driving the LDMOS transistor into secondary breakdown.[6]



2. The approximate electric field along the surface of the device can be estimated for several LDMOS drain configurations.

The secondary breakdown effect is encountered because of the parasitic bipolar transistor inherent in an LDMOS transistor. The effect is exacerbated by the shallow drain diffusion incorporated into all current commercial devices. The shallow drain is necessary to reduce the Miller capacitance (from gate to drain), which is critical for high-frequency operation. This, in turn, produces very high electric fields in the drain, a result of dropping a high voltage (~28 V) across an extremely narrow distance (~0.4 μm).

Secondary breakdown has long been known as a frequency-dependant effect. This is due to the accumulation of hot electrons into a destructive current of sufficient magnitude to harm the device (over time). For high-frequency silicon power transistors, the current/voltage swing across the drain is sufficiently swift that destruction usually can't occur. However, if the high-frequency device is then used in a low-frequency application, or is modulated with lower-frequency signals at high peak powers, a destructive current has more

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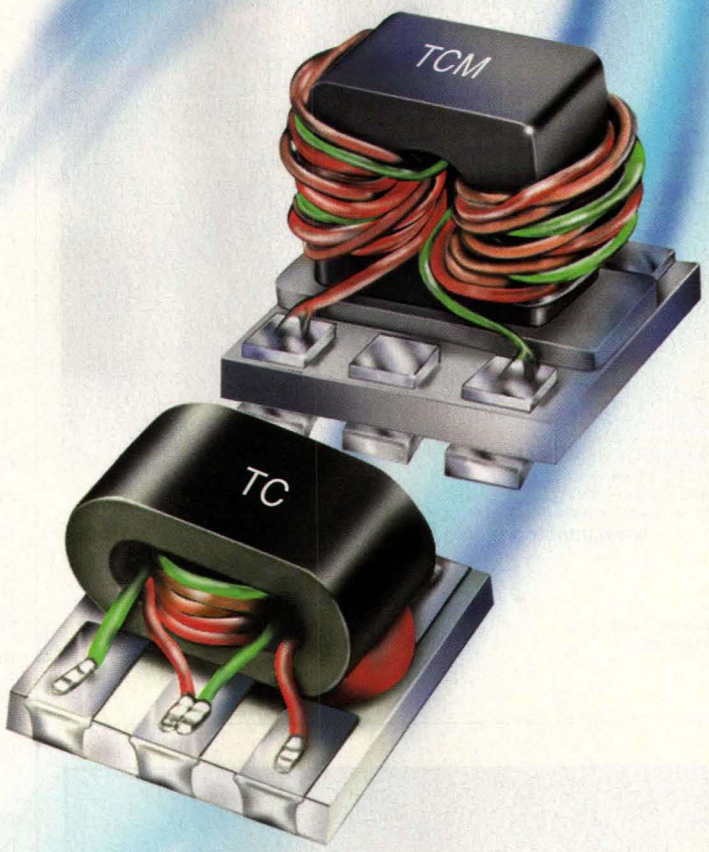

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TC4-14	4A	200-1400	800-1100	1.29
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TC9-1	9A	2-200	5-40	1.29
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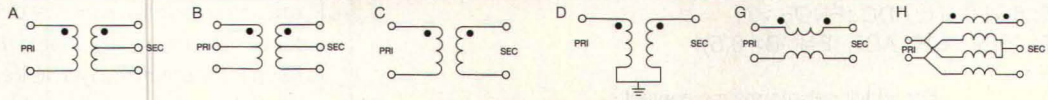

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time to accumulate. Under such conditions, a device could then be damaged and nonlinear power distortion will likely be apparent in the device's output waveforms.

This onset of secondary breakdown is most likely the effect recently described as a "memory" effect.[4,5] In such a case, the electric field in the device is sufficiently high, and the current through the drain is high enough, to trigger secondary breakdown. This results in distorted output waveforms with observable harmonic nonlinearities, although is usually not serious enough to damage the LDMOS device. The device's capacitor network tends to reduce this distortion by attempting to hold the drain current constant. An interesting experiment would be to study the distortion of the LDMOS device at much-lower frequencies, since it is expected that intermodulation distortion (IMD) would increase dramatically under secondary breakdown conditions. For this reason, most production microwave LDMOS devices cannot run safely at frequencies below 100 MHz.

Secondary breakdown is also the reason that all high-frequency power bipolar transistors require emitter ballast resistors—to reduce this effect. Power transistors that operate above several hundred megahertz require these ballast resistors to limit these destructive effects and provide reliable operation. Lower-frequency power transistors (in the kilohertz range) operate reliably without them, simply because they have much wider base widths and much thicker collector regions. The wider bases and thicker collectors (analogous to the drains of a power FET) dramatically lower the electric field in the device, reducing the tendency to be driven into secondary breakdown. Base widths (or channels) of low-frequency devices tend to be many microns in length, compared to fractions of a micron for high-frequency devices. Collectors (drains) in lower-frequency devices are similarly thicker, providing a measure of localized ballast.

A sketch of a typical LDMOS device (**Fig. 1**) indicates the position and thick-

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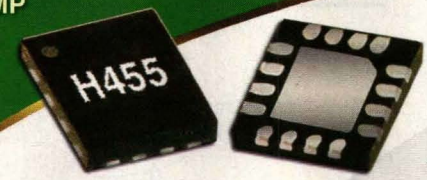

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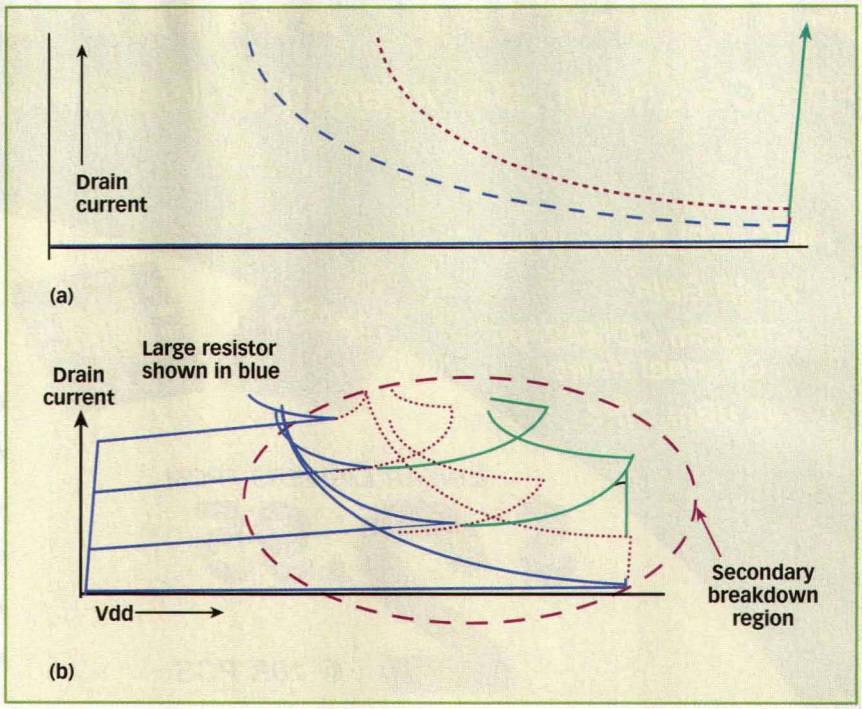
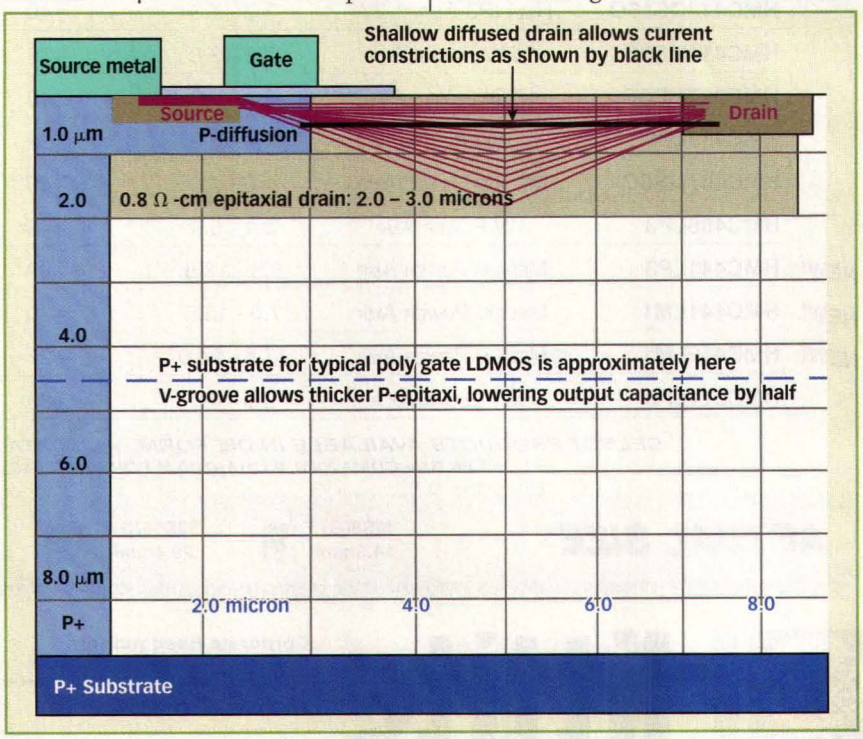


3. Breakdown voltage (a) and device transfer characteristics (b) can be altered with different resistance values across the parasitic bipolar and drain thicknesses.

ness of the drain. The figure also shows a self-aligned shadow-isolated device with a much-thicker epi drain, believed to be free from ALL hot electron effects. Note that the 2.5-µm-thick N-drain epitaxial region and 8-µm-thick P-epitaxial layer reduces the field in a thick-drain LDMOS device by roughly an order of 5 to 10 over a conventional polygate LDMOS device utilizing a shallow diffused drain.



4. The current flow (in red) is restricted by the 0.4-µm shallow diffused drain, which also influences the operating point at which nonlinear effects become significant.

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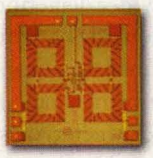

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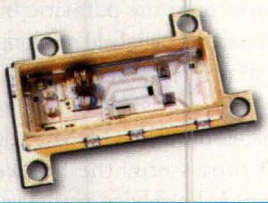

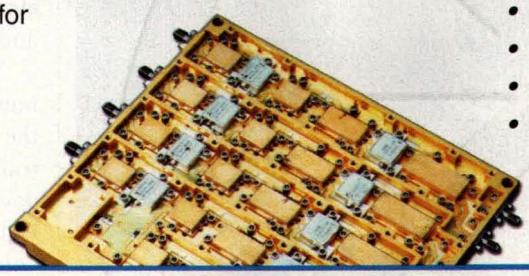

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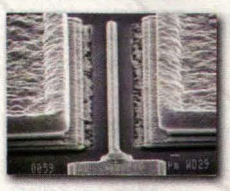

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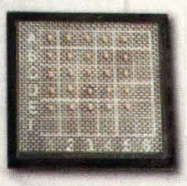

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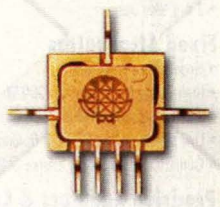

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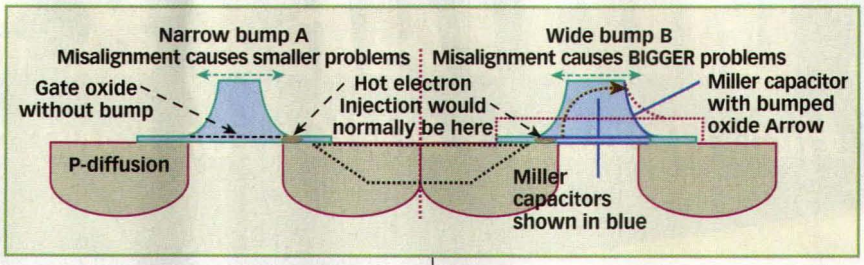
The thicker epitaxial drain also allows higher saturated drain current, increasing device linearity at high current.

The electric fields in the two LDMOS devices can be approximated by **Fig. 2**. The thick-drain device allows for about a 5-to-10-fold reduction in the electric field (due to the much-wider depletion region). This should allow for both an elimination of the threshold shift problem and a dramatic improvement in secondary breakdown characteristics, supporting operation at significantly lower frequencies. This, in turn, should eliminate the long-term threshold drift and short-term memory effects.



5. Modification to a basic vertical DMOS resulted in improved linearity and stability at lower frequencies. Note improvement in Miller capacitance indicated by the dashed arrow.

The effects of the parasitic bipolar transistor and the high field resulting from the thin drain region can be seen in the transfer characteristics and the breakdown voltage of various LDMOS devices. **Figure 3** shows how the breakdown voltage and the device transfer characteristics can be altered by decreasing the resistance across the parasitic bipolar transistor and increasing the drain thickness.

One of the most dramatic improvements made possible by the thick-drain LDMOS configuration is the improvement in the current-carrying capability of the device. This allows not only a reduction in the on-resistance[7] of the device, but also a substantial improvement in the high-current capability of the device, increasing linearity at high power levels. **Figure 4** compares the current flow in a thick-drain LDMOS device to that of a LDMOS device with shallow drain with conventional (non-self-aligned) polygate. Note that current is restricted by the 0.4-µm shallow diffused drain. This not only effects the maximum current capability of the device, but also the point at which nonlinear effects begin to influence the device at higher currents.

An early version of a shadow-isolated LDMOS device allowed for a 50-W

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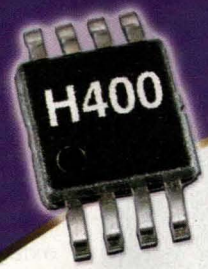

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	HMC410MS8G	High IP3, DBL- BAL	9.0 - 15.0	DC - 2.5	-7.5	40	+24	$4.55
	HMC175MS8	+13 LO, DBL- BAL	1.7 - 4.5	DC - 1.0	-8	30	+20	$1.74
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pulsed device with 7-dB gain across the 960-to-1215-MHz band. The design, which was fabricated with the same processes used for vertical DMOS device production at the time, traded gain for bandwidth. The early LDMOS devices suffered from very high Miller capacitance since they had no thick oxide bump over the drain **(Fig. 5)**.

Once the hot electron problem had been resolved, a modified device structure is proposed which would dramatically improve the inherent linearity of the shadow LDMOS structure of Fig. 1. The new approach was discovered by accident some years ago. While working on a contract to improve the linearity of a low-frequency (2-to-30-MHz) device for a military customer, a puzzling observation was made. In this case, the structure of a 1-GHz device was modified to lower its Miller capacitance and improve its high-frequency performance. The modified device incorporated a manually aligned "thick oxide bump" over the drain portion of the gate oxide of a vertical DMOS device. Since the devices were shadow isolated, the parasitic resistor across the emitter-base junction (of the intrinsic bipolar) was already minimized, so it was felt that the resulting DMOS device should operate reliably at much-lower frequencies,

> ***The secondary breakdown effect is encountered because of the parasitic bipolar transistor inherent in an LDMOS transistor.***

even though the lower Miller capacitance wasn't beneficial at the much-lower frequencies. The work was important because the military contract required thousands of reliable high-power devices.

With this modified device, it was possible to parallel eight 50-W 1-GHz chips into a push-pull beryllium-oxide (BeO) package to achieve 300 W output power even at *lower frequencies*, essentially due to the "accidental" construction of the manually aligned oxide "bumps," intended for better *high-frequency* response. One wafer from the production lot (which was chosen because the lot yielded thousands of chips for the linearity experiment) exhibited dramatic improvement in device linearity. An improvement of approximately 6 to 8 dB in IMD performance was observed, which was puzzling for a long time. The sketch in

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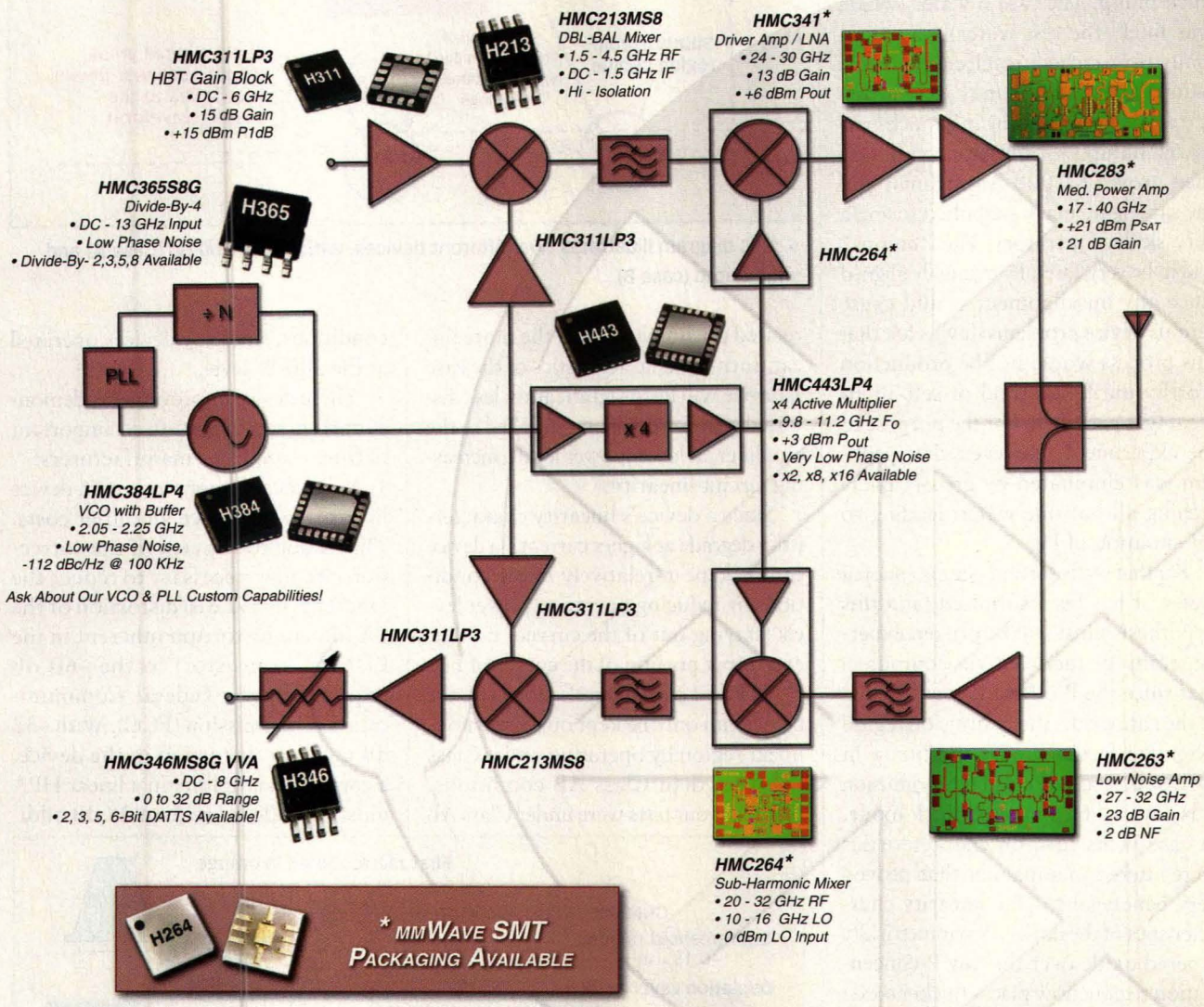

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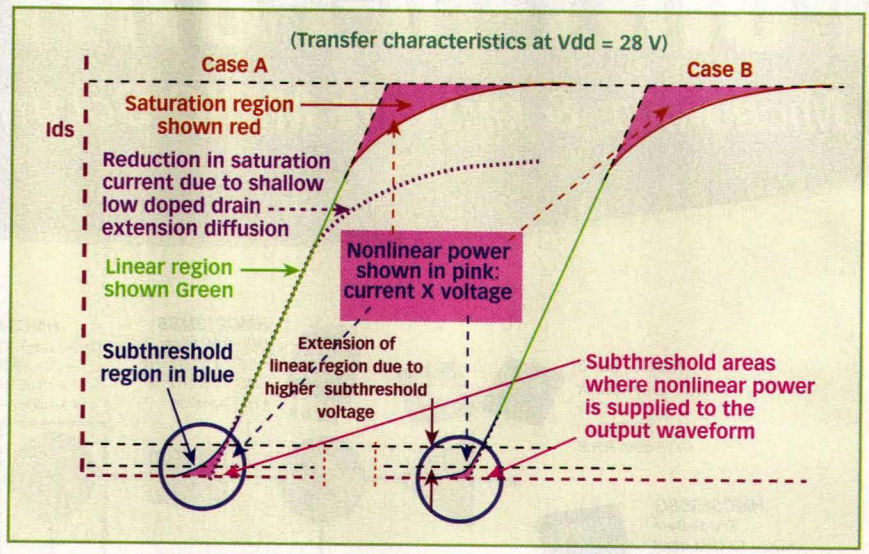
Fig. 5 demonstrates what most likely happened and why a similar self-aligned device with dramatically improved intermodulation characteristics now seems feasible.

The "bumps" were created by applying the gate mask to the wafers with a thick oxide and over-etching (under-cutting the images) sufficiently to create a thick bump. The case B wafer (which was likely the test wafer) was minimally over-etched, resulting in a wide bump. The case A wafers were grossly over-etched, resulting in a much-narrower bump. A thin gate oxide was then grown (~1000 Angstroms) and the same gate mask reapplied (using a very skilled operator). The "bumps" had to be very carefully manually aligned since any misalignment would cause serious device problems. It was felt that this process would not be production worthy until a method of self-alignment was perfected. For the purpose of the experiment, however, that problem was eliminated by grossly over-etching all but one wafer, leading to the situation of Fig. 5.

For that wafer lot and one exceptional wafer, it has been surmised (and this hypothesis must still be proven experimentally or modeled via computer) that since the P-diffusion was aligned to the gate oxide, the P-diffusion region extended farther under the bump in the case B. Since the tail of the P-diffusion was covered by a tapered thick oxide, in case B, its turn-on characteristics were altered in a manner that proved very beneficial for the linearity characteristics of the device. A symmetrically tapered oxide over the low P-concentration region, now places thicker oxide over the low threshold region of the channel, actually increasing its subthreshold (low-current) turn-on voltage. Two devices resulted: narrow bump (case A) and wide bump (case B) devices of **Fig. 6.**

Note that the saturation region of the MOSFET is unaffected by the thick oxide. However, the low-current region should have much more linear characteristics, over the lower-current ranges. If IMD is considered a power-related phenomena, then the more linear (turn on) characteristics of the case B device will keep significantly less distorted power from being supplied to the amplifier, at lower power levels, increasing circuit linearity.

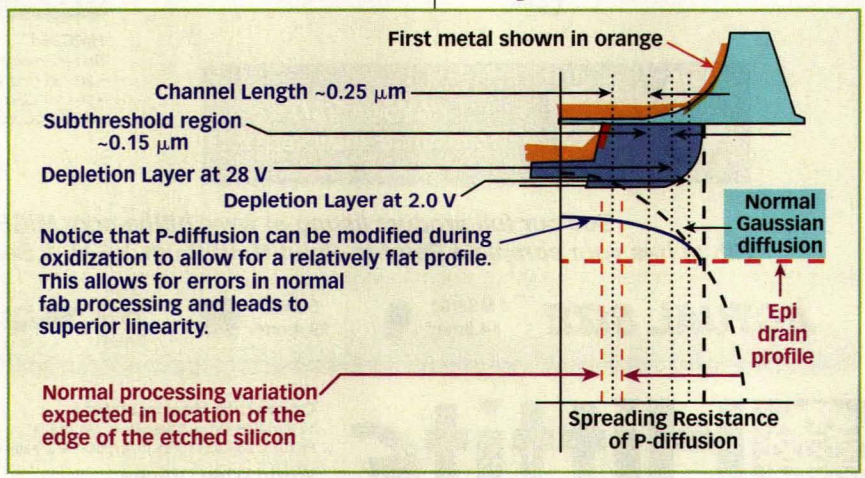


6. This diagram illustrates two different devices, with narrow bump (Case A) and wide bump (case B).

Since a device's linearity characteristics degrade at higher current,[5] a device can be kept in relatively linear conditions by reducing operating power levels (staying out of the curved, nonlinear, upper portion of the curves of Fig. 6). At lower current levels, however, the device can only be kept out of the nonlinear region by operating under Class A rather than Class AB conditions. Note that our tests were under Class AB conditions, since the devices operated at the 300-W level.

These device improvements demonstrate two significant effects important to linear amplifier manufacturers:

1. A significant improvement in device linearity will reduce amplifier costs. This is due to the cost of the correction circuitry necessary to reduce the inherent (≈ –32 dB) distortion of the PA (due to distortion inherent in the LDMOS transistor) to the –60 dB required by the Federal Communications Commission (FCC). With –32 dB inherent distortion in the device, a correction amplifier in a linear HPA must provide more than 28 dB addi-



7. This profile shows how diffusion can be controlled to improve device yield and linearity even when considering silicon-semiconductor-process variations. Note that the process allows very short channel length and consistent electrical parameters.

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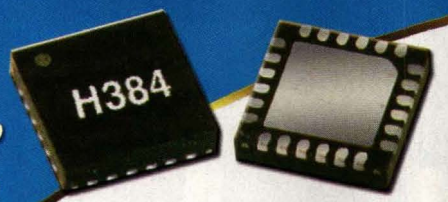

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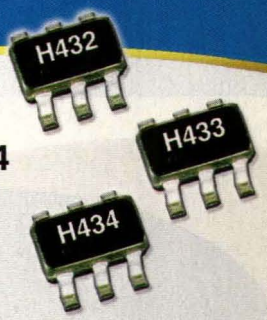

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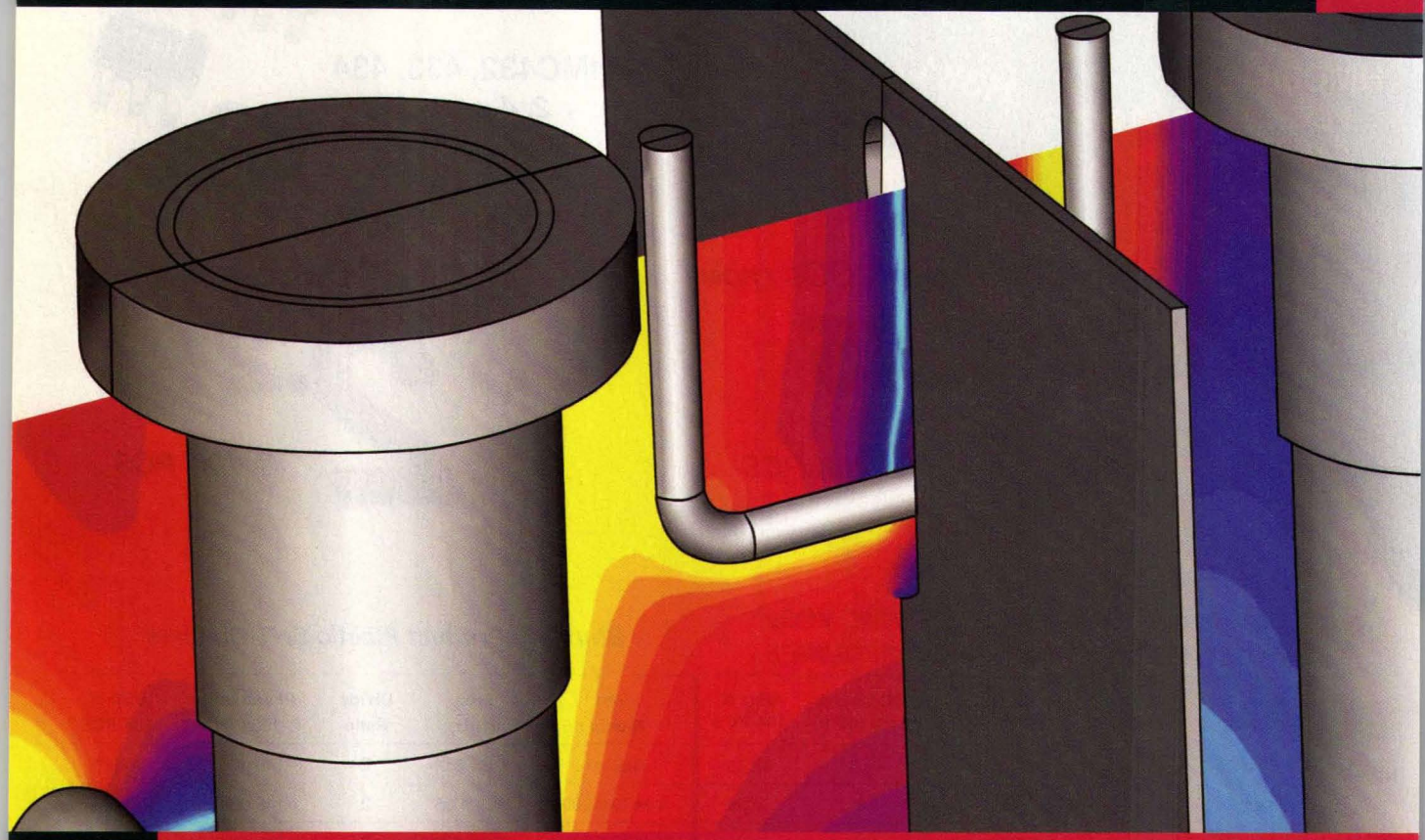

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tional correction. This requires an expensive correction amplifier and adds to the cost of the complete HPA. If the transistor distortion is lowered by 6 to 8 dB, the correction amplifier must only supply ~20 to 22 dB of correction. This amount of correction can be supplied by a simple and relatively inexpensive Class A amplifier, lowering the overall cost of the HPA.

2. Shadow-isolated LDMOS devices are nearly immune from the hot-electron-injection threshold drift (HEI) inherent in all current commercial LDMOS devices **(Fig. 7)**. However, if any tendency for HEI exists in the shadow LDMOS, it should occur in the region indicated by the purple ovals of Fig. 5. Within this region the electric field is at its highest level and hence the hot-electron problem is most likely to occur. Note that in the shadow-isolated LDMOS device, the region of maximum field is protected by a thicker oxide (over the high-electric-field region). The reduced electric field should minimize any secondary breakdown or drift problems, should they occur in the shadow LDMOS device. Since secondary breakdown characteristics are also significantly improved, the "memory" effect should also be eliminated or at least minimized. A much-more-rugged device should also result, capable of stable operation at lower frequencies while providing improved high-frequency performance.

The self-aligned tapered oxide portion of the shadow-isolated LDMOS device can easily be optimized for significantly improved device linearity. This effect would be nearly impossible to optimize on a more-conventional polygate device. The shadow-isolated device employs self-alignment to accurately locate the bump and shape it over the channel diffusion. This should allow its location and shape to be reproduced within a few hundred angstroms from lot to lot, allowing extremely high-yield LDMOS devices with dramatic improvements in device linearity. MRF

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Electrically tunable preselectors are key elements in communications, avionics, and radar receivers. Narrowband RF and microwave preselectors prevent large off-channel signals from overdriving a receiver front end. Microstrip combline and interdigital tunable filters have been described by several authors.[1-5] By combining a suspended-stripline bandpass filter (BPF), microstrip low-noise amplifier (LNA), and input/output matching networks, an electrically tunable L-band preselector can be assembled with typically 3-dB bandwidth from 18 to 24 MHz.

The tunable BPF is split to provide partial selectivity with minimum insertion loss prior to amplification for improved input noise figure. The first two-pole filter before LNA prevents undesirable signals from overdriving the LNA. The second three-pole filter after the LNA provides selectivity against receiver image and spurious frequencies. The three-pole BPF placed after the LNA has a negligible effect on the overall preselector input noise figure.

A conventional combline filter **(Fig. 1)** consists of a set of parallel-grounded resonators loaded by the variable capacitors made of tuning screws. Combline filter can be realized on different transmission lines. Suspended stripline provides high quality factor (Q) of approximately 500, stability over a wide temperature range, and high impedance range.[6] In the high-Q suspended stripline **(Fig. 1b)**, the parallel strips are printed on both sides of a substrate in a symmetrical configuration. Plated through holes (vias) provide electrical connection between top and bottom conductors. When dual-center conductors are located symmetrically with respect to each other, they are excited in phase, causing most of the electromagnetic field to propagate in the air dielectric. Therefore, substrate dielectric losses and dielectric constant variations have negligible effects on the attenuation and phase velocity of the transmission media.

Suspended stripline resonators are placed between two parallel ground planes. Adjacent suspended stripline resonators are coupled by the fringing fields. The typical length of the combline filter resonators is between $\Lambda_0/16$ and $\Lambda_0/6$, where Λ_0 is the center guide wavelength at the resonator. For this resonator length, magnetic cou-

Table 1: Comparing combline filter configurations

BANDPASS FILTER PARAMETERS		TWO POLES	THREE POLES	FIVE POLES
Insertion loss at 1030 MHz	(dB)	1.2	2.1	3.4
Bandwidth at 3-dB level	(MHz)	41.0	29.0	25.0
Return loss	(dB)	20.3	23.5	20.7
Second-harmonic attenuation at 2060 MHz	(dB)			94.8
Third harmonic attenuation at 3090 MHz	(dB)			94.6

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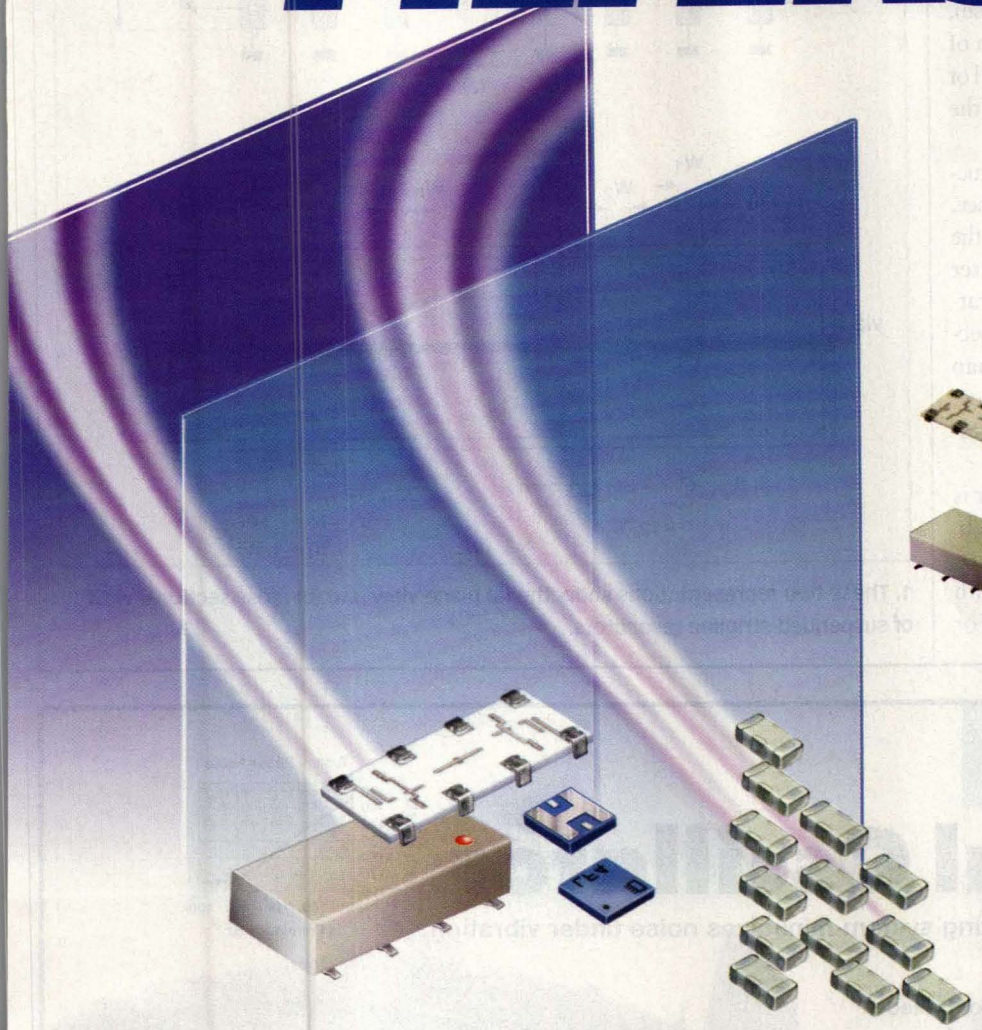

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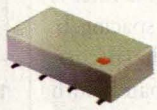

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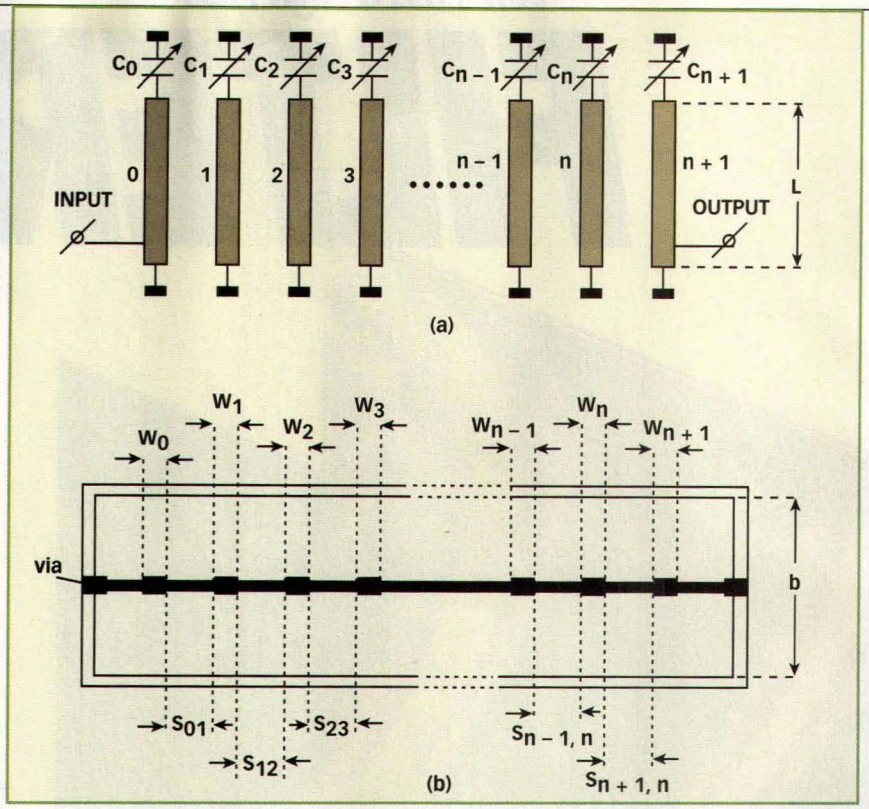
pling predominates.[7] The minimum practical length of the resonators is limited by the Q. Practical Q values are dependent upon the ground-plane spacing (base), the frequency of operation, the finish of the ground surface, the plating material of the printed-circuit board (PCB), and the suspended-stripline structure.

Short resonators yield a compact structure with excellent stopband performance. With a resonator length, l, of $l = \Lambda_0/8$, the second passband will appear at better than four times the fundamental operating frequency, while at $l = \Lambda_0/16$, the second passband will occur at more than eight times the fundamental frequency. Combline filter trade-offs for various resonator lengths are described in ref. 4.

The bandwidth of a combline filter is a function of the ground-plane spacing, b, to wavelength ratio, b/Λ_0 and the spacing, S, between resonators. The bandwidth increases with higher S and b/Λ_0. For



1. These two representations show the (a) plane view and (b) cross-sectional view of suspended-stripline resonators.

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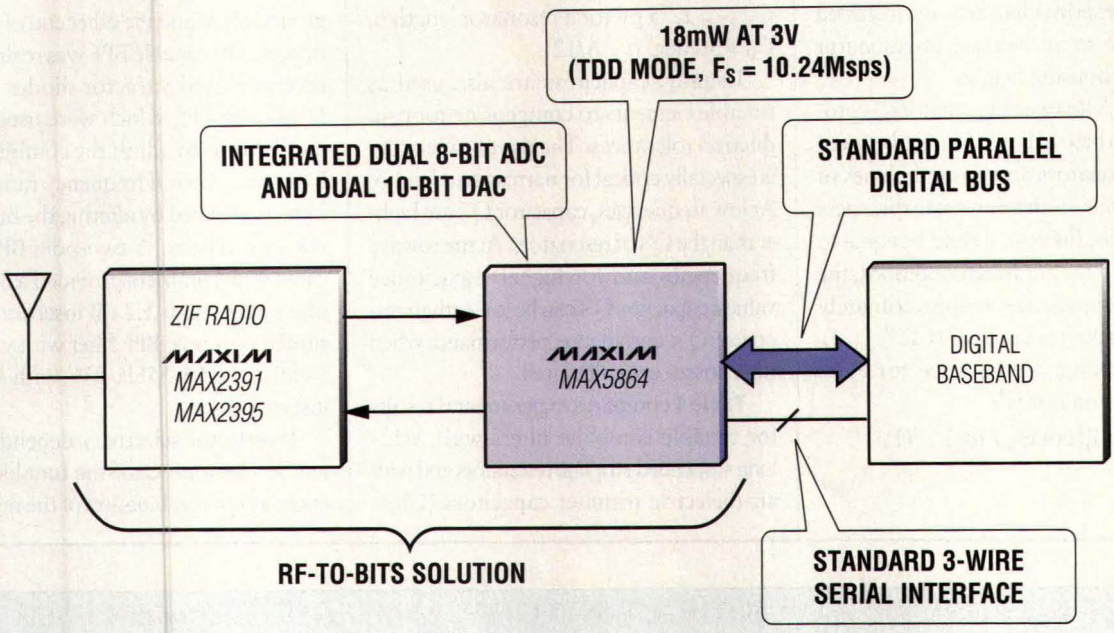

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combline filters, bandwidths of 2 to 50 percent can be achieved.

The spacing (b) between two ground planes (cover and housing) defines resonator impedances and lengths and maximum power and Q. Resonator impedances range from 70 to 140 Ω at frequencies (f) of $f \leq 1$ GHz. Large bases (ground planes) lead to higher power handling and increased Q, but also to an increase in resonator length and housing height.

Spacing S (between resonators) is proportional to base b. For a distance between printed resonators and ground planes of b/2 = 200 mils, with a substrate thickness (h) of 10 mils, the base should be equal to b + h = 410 mils. For these conditions, the resonator impedance is approximately 100 Ω (an admittance of 0.01 Ω^{-1}.

The loading capacitance for each combline resonator is[1]:

$$C_{TOT} = Y_i(\cot\Theta_0 / \omega_0) \quad (1)$$

where:

Y_I = the admittance of the ith resonator when the (i – 1)th and (i + 1)th resonators are shorted and $\Theta_0 = (2\pi l)/\Theta_0$ = the electrical length at the center frequency.

For 1-GHz suspended-stripline resonators with the above dimensions, the guide wavelength is equal to Θ_0 = 28.8 cm. According to Eq. 1, the total capacitance, C_{TOT} = 2.75 pF for a resonator length of Θ_0 = 30 deg. ($l = \Lambda/12$).

Usually, capacitors are also used as tunable elements to compensate for production tolerances. The use of capacitors is especially critical for narrow bandwidth. At low frequencies, capacitor Q's are higher than the Q's of resonators. At microwave frequencies and for higher capacitance values, capacitor Q's can be lower than resonator Q's, dominating performance when filter losses are calculated.

Table 1 compares experimental results for tunable combline filters with Λ/12-long suspended-stripline resonators and with air-dielectric trimmer capacitors (Giga-Trim products from Johanson Corp., Boonton, NJ) with capacitance range of 0.4 to 2.5 pF.

Figure 2a shows an electrically tunable BPF consisting of suspended-stripline resonators grounded at one end, high-Q GaAs varactor diodes, and lumped-element loading capacitors between the ground plane and the other end of each resonator. The tunable BPF was realized with reverse-biased varactor diodes D_1, D_2, D_3, D_4, and D_5 which were used as tuning elements to adjust the combline passband over the full frequency range. Tuning is performed by altering the bias of the varactor diodes. A two-pole BPF fabricated with trimmers provided a 3-dB BW of 41 MHz with 1.2 dB insertion loss. A similar two-pole BPF filter with varactors yielded a 63.8-MHz BW with 1.85-dB insertion loss.

Preselector selectivity depends on filter Q. The total Q of the tunable BPF is taken as the combination of the resonator,

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loading capacitor, and varactor diode Q's. For a low-loss L-band combline filter, the varactor diode Q is an very important parameter. The Q of the best varactor diodes is lower than that of the suspended stripline resonators and loading capacitors, and is a dominating factor when calculating filter losses.

To increase diode Q, GaAs varactors can be used. For example, model MA46617 GaAs abrupt varactor diodes provide a Q of 210 at 1 GHz and serve as effective variable capacitors. For the MA46617 diodes, the total capacitance ratio, C_{T0}/C_{T45} = 4.4 to 6.9, where C_{T0} and C_{T45} are the varactor capacitances at 0 and 45 V, respectively. Varactor tuning voltages are controlled by a microprocessor to precisely tune the filter response.

The total loaded capacitance of combline tunable filter is given by:

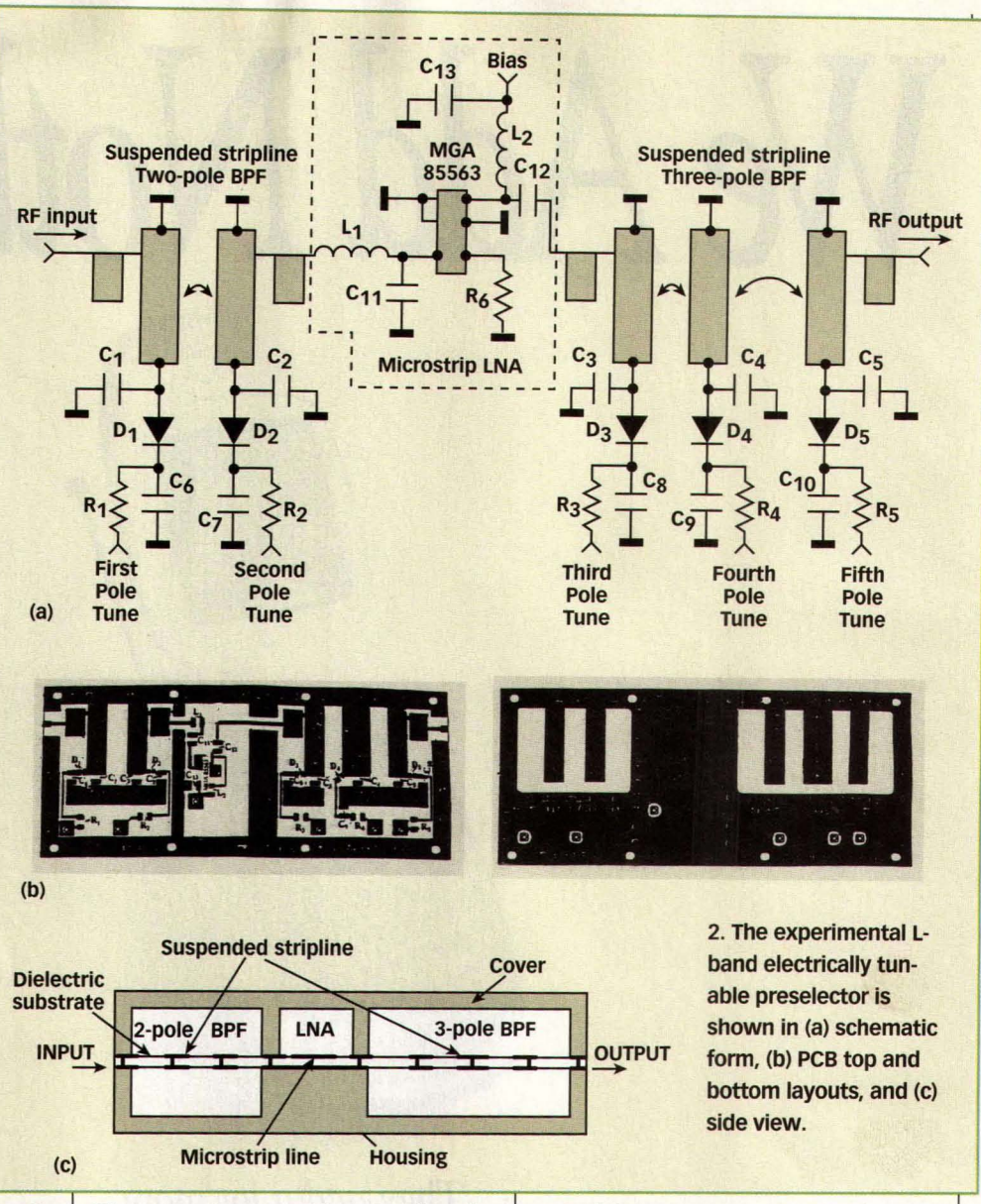
$$C_{TOT} = C_j + C \qquad (2)$$

where:

C_j = the varactor diode junction capacitance and

C = the parallel lumped-element capacitance ($C_1 = C_2 = C_3 = C_4 = C_5 = C$). The center frequency of the tunable preselector is determined by lengths of resonators and the total loaded capacitance, C_{TOT}.

For the 1-GHz tunable filter with resonator length of l = L/12, the total capacitance (from Eq. 1) is C_{TOT} = 2.75 pF. For a 25-percent tuning range, varactor diodes with a junction capacitance of Cj = 1.3 pF at –4 VDC can be used. In this case, the lumped-element capacitance (according to Eq. 2) should be C = 2.75 – 1.3 = 1.45 pF. To allow for biasing, capacitors C6, C7, C8, C9, and C10 are added (Fig. 2a).



2. The experimental L-band electrically tunable preselector is shown in (a) schematic form, (b) PCB top and bottom layouts, and (c) side view.

These capacitors provide an RF short for the varactors and an open circuit for the bias currents.

The tunable preselector is based on a combination of suspended-stripline and microstrip transmission lines. Each of these two transmission-line formats offers certain strengths.[6] Microstrip, for example, supports a high level of integration and excellent heat dissipation, since a good ground connection (with minimal reactance) is needed for each device. The tunable preselector includes a microstrip LNA between the first and second suspended-stripline BPF. The LNA is based on a monolithic-microwave-integrated-circuit (MMIC) MGA-85563 device from Agilent Technologies.[8] The RF layout of the LNA is shown in **Fig. 2b.**

The LNA operates from a +3-VDC bias supply and draws nominal current of 15 mA. For the lowest noise-figure performance, the amplifier's input port should be matched with the output of the two-pole combline filter and the input of the three-pole combline filter. To match the input of the LNA to the 50-Ω two-pole BPF output, inductor L_1 is placed in series with the input of the LNA. DC blocking capacitor C_{12} is placed at the output of the MMIC LNA to isolate the amplifier from the three-pole BPF. Inductor L_2 and capacitor C_{13} isolate RF from the DC supply.

A circuit that includes the MMIC LNA and its input and output matching networks was realized on a microstrip line using the same BPF dielectric substrate. The

Table 2: A summary of L-band preselector performance

FREQUENCY (MHz)	3-dB BANDWIDTH (MHz)	INPUT RETURN LOSS (dB)	INPUT NOISE FIGURE (dB)	GAIN (dB)
962	18.1	23.7	4.6	4.5
1090	20.8	20.6	3.8	6.0
1213	24.4	26.3	4.0	7.0

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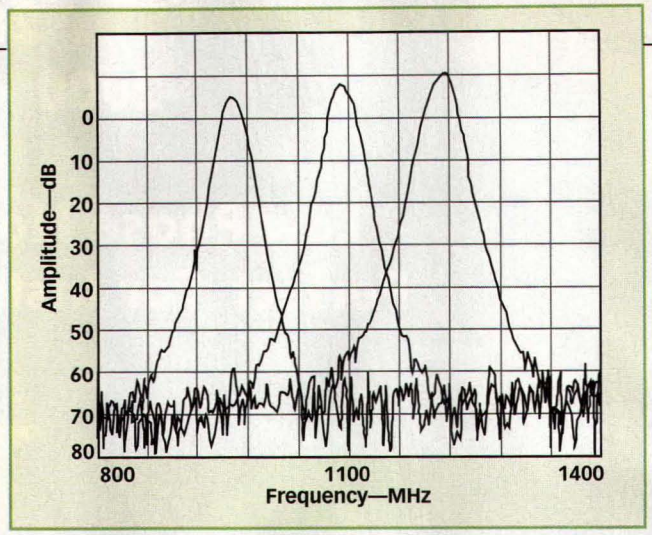
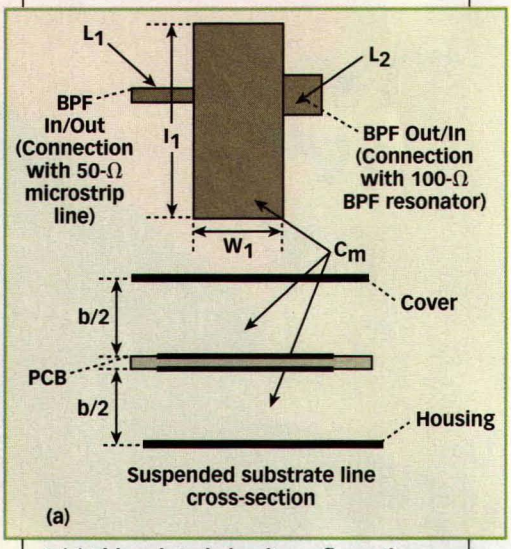
combine-filter input/output network provides a transition from the microstrip-line LNA to the suspended-stripline BPF as well as matching between the LNA input/output ports and the suspended stripline resonators. For low-frequency application (less than 1 GHz), a straight connection between microstrip and suspended stripline can be used. This connection includes the step between center conductors of two lines and ground plane step **(Fig. 2c)** to provide a 50-Ω impedance for both lines. For higher-frequency applications, the special transition between the two lines can be used.[6]

Matching sections at the filter input and output match the resonators with the 50-Ω microstrip lines. Each matching network **(Fig. 3)** consists of two high-impedance suspended-stripline series printed inductors (L_1 and L_2) and low-impedance suspended stripline (shunt capacitance C_m). This matching network is equivalent to the T-section of the LPF **(Fig. 3b)**.

The main parameters of the matching network can be determined using the wave-matrix method. This matching circuit is a two-port network, which is equivalently represented in the form of four cascade-connected elementary two-port networks (Fig. 3b). The resulting transfer matrix of the equivalent two-port network is equal to the product of the transfer matrices of the above component two-port networks written down in the order of energy flow.



4. Preselector response was tested from 800 to 1400 MHz.



3.(a) This printed-circuit configuration shows the combline BPF's matching circuitry.

Multiplying the transfer matrices for the center frequency yields:

$$T_{21} = Z_1 + Z_3 - 2Y_2$$
$$+2Z_1Y_2 - Z_3Y_2 + 1 \qquad (3)$$

For the case of perfect matching of input port 1, element S_{11} of the scattering matrix, which has the physical meaning of reflection coefficient, must be equal to zero, $S_{11} = T_{21}/T_{11} = 0$; therefore, $T_{21} = 0$. If $Z_1 = Z_3 = Z$, it is possible to obtain from Eq. 3:

$$Y_2 = (2Z + 1)/(2 - Z) \qquad (4)$$

From Eq. 4, it is possible to find the value of the capacitance matching element and its dimensions.

Using these techniques, the preselector was fabricated on 10-mil-thick dielectric substrate TLE-95™ from Taconic Advanced Dielectric (Germantown, NY) with dielectric constant of 2.95. The PCB was suspended over a silver-plated aluminum machined housing. The depth of the housing and cover was 0.200 in. (0.508 cm). The total dimensions of the preselector are 12.7 × 5.08 × 1.27 cm.

Figure 4 shows the frequency response of the preselector for various varactor tuning voltages. As the filter tunes from 962 to 1213 MHz, its 3-dB bandwidth varies from 18.1 to 24.4 MHz. **Table 2** summarizes the preselector's performance. MRF

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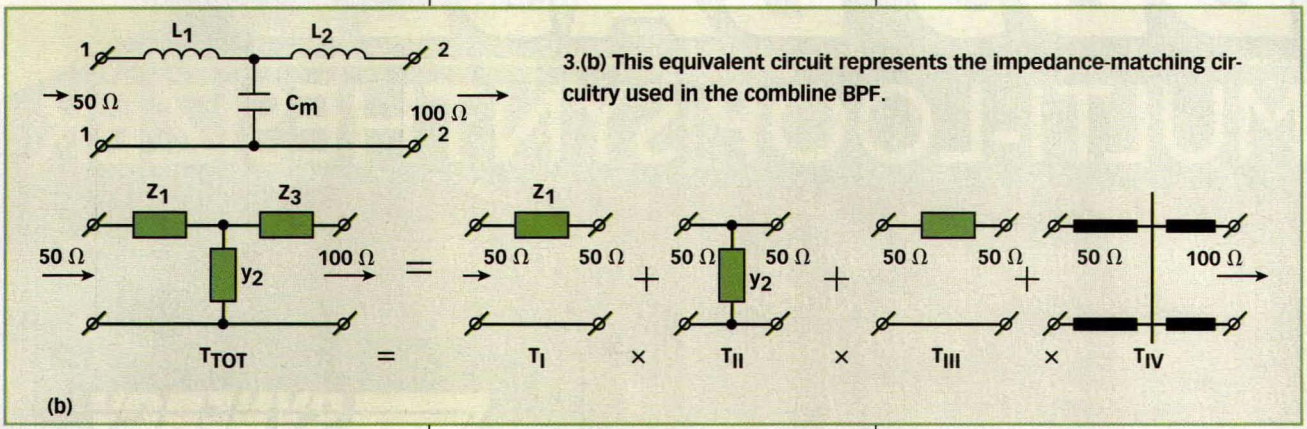

3.(b) This equivalent circuit represents the impedance-matching circuitry used in the combline BPF.

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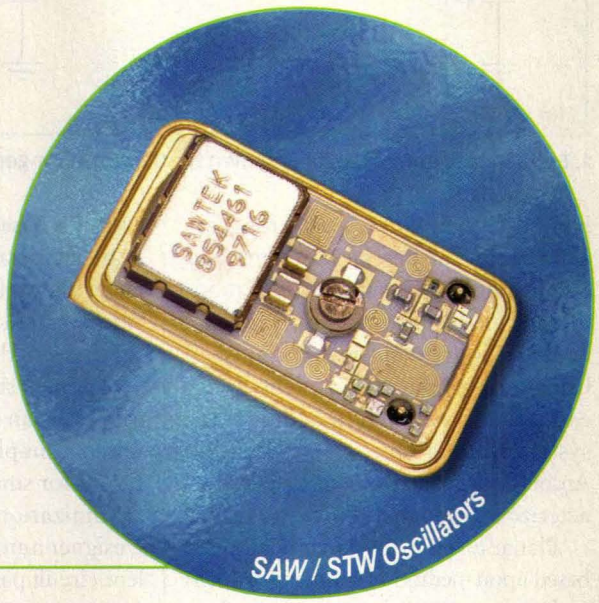

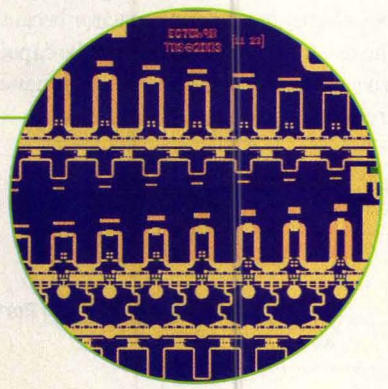

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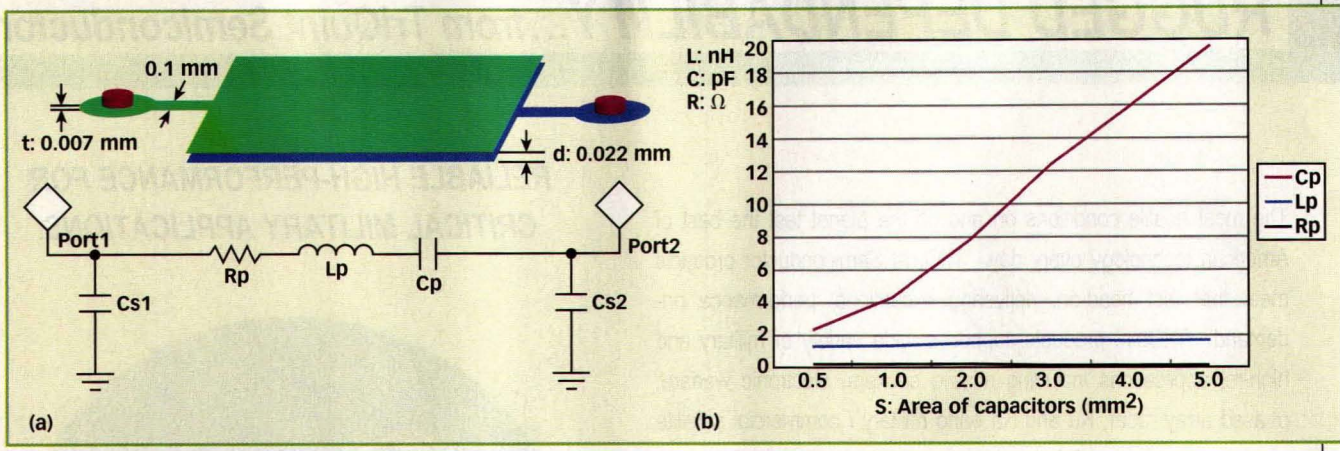


1. Extracted performance (b) is shown for the capacitor geometric model and equivalent circuit (a).

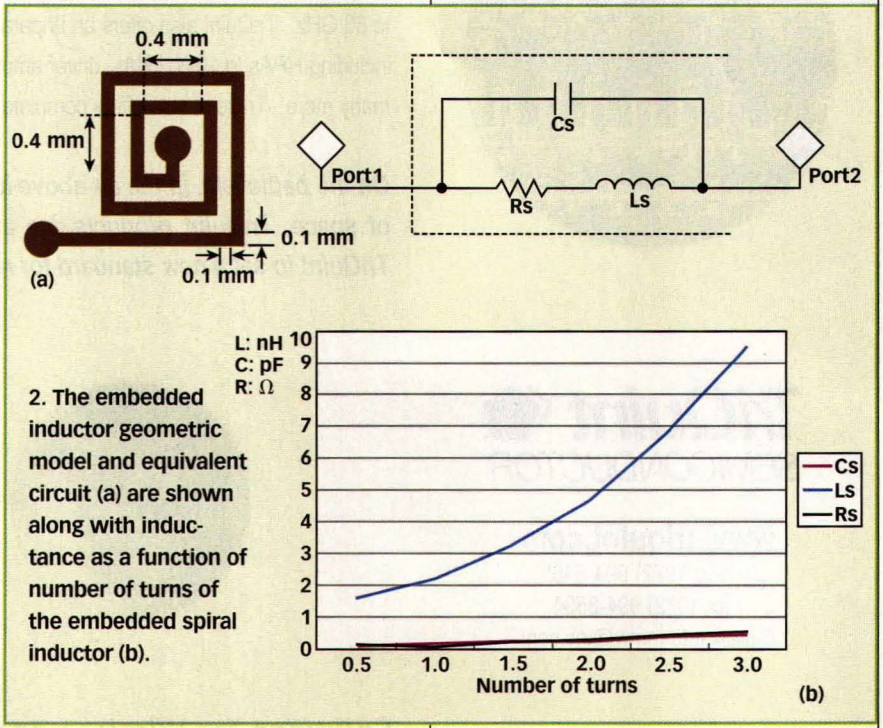
EM-based simulation is used for characterization of passive elements and circuit simulation is used for RF module design and optimization. Model library development is accomplished using an integrated equivalent-circuit extraction capability. In addition, the system simulation integrated within Ansoft Designer allows users to fully characterize the design at the system level.

Planar EM is a 3D planar field solver based upon method-of-moments (MoM) techniques. With its singular-value-decomposition (SVD) FastSolve technology, Planar EM can simulate very complex structures, allowing designers to characterize the complexities found in LTCC modules. HFSS can be used to examine structures that are not strictly planar, and can perform packaging analysis, making it possible to characterize the effects of module interconnection to a higher-level assembly.

The procedure for building embedded passive models and an embedded passive model library is the same for LTCC modules and for printed-circuit boards (PCBs). The procedure begins with physical model analysis using some form of EM simulation. HFSS, Planar EM, or Spicelink 3D can be used to extract electrical performance. HFSS is a full-wave 3D solver and should be used for high frequencies and complex geometries. Often the embedded passive devices are predominantly planar in nature with minimal coupling to other 3D elements. In this case, the built-in Designer Planar EM is the best choice. Spicelink 3D is similar to HFSS; however, it is based upon a static field solution. It typically completes simulation faster than HFSS and should be used whenever the structure is small compared to wavelength.

The next step in model development is to select an equivalent-circuit model. Often a simple pi or T network is sufficient for small two-terminal devices. Optimization engines within Ansoft Designer automatically adjust equivalent-circuit parameters until circuit performance matches the EM simulation extracted electrical performance.

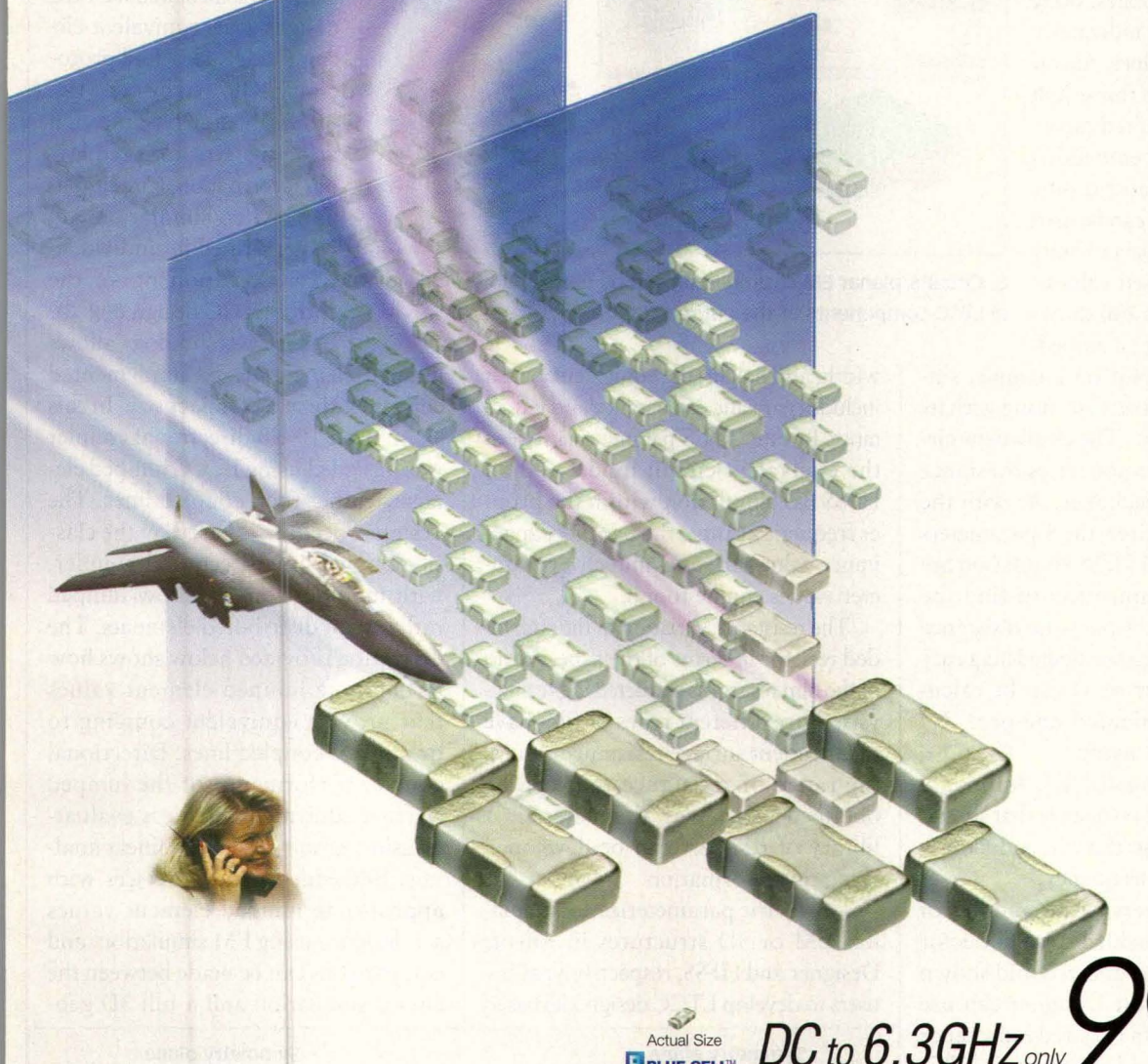
An embedded capacitor geometry and its associated equivalent circuit are shown in **Fig. 1(a)**. The geometry is a simple parallel-plate structure. The equivalent circuit includes parasitic resistance and inductance as well as fringing capacitances. Parallel capacitance value and parallel parasitic parameter values can be found by fitting the S-parameters between the equivalent-circuit model and performing HFSS 3D simulation within the proper frequency range. The Q value can be calculated from a terminated one-port Z_{11} parameter using $Q = \text{mag}[\text{imag}(Z_{11})/\text{real}(Z_{11})]$. The self-resonance frequency (F_r) should be investigated for any capacitor because the reactance value of may not be capacitive at frequencies above the resonance frequency.



2. The embedded inductor geometric model and equivalent circuit (a) are shown along with inductance as a function of number of turns of the embedded spiral inductor (b).

Low Pass & High Pass

LTCC FILTERS



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LFCN-1000	DC-1000	1225	1700	5
LFCN-1200	DC-1200	1480	1750	7
LFCN-1325	DC-1325	1560	2100	5
LFCN-1750	DC-1750	2025	2325	7
LFCN-2000	DC-2000	2275	3000	5
LFCN-2250	DC-2250	2575	2850	7
LFCN-2400	DC-2400	2800	3600	5
HFCN-650	850-2490	650	480	7
HFCN-740	900-2800	740	550	7
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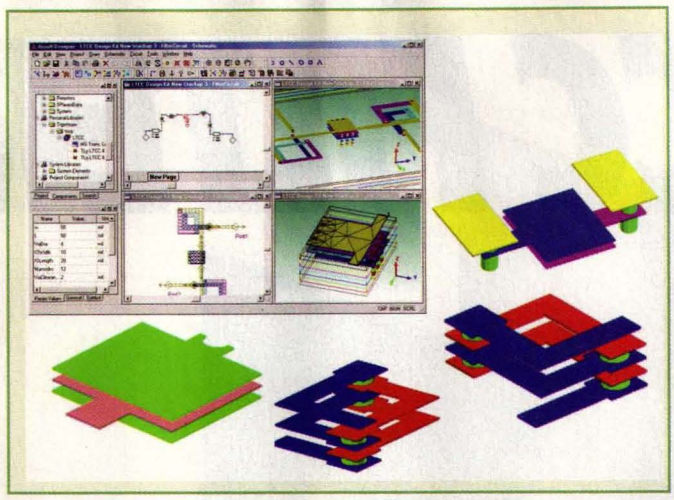


3. Circuits/planar EM cosimulation can be performed for individual LTCC components or the entire LTCC design.

Figure 1(b) shows the variation of capacitance value of the embedded capacitor in terms of the overlapped area between parallel plates, along with the parasitic inductance and resistance values. Ansoft Designer can use this graph to obtain the required capacitance value by embedded parallel plates, and results from the analysis can be used to construct a capacitor library for frequently used values.

Similarly, **Fig. 2(a)** shows the geometry for an embedded inductor based on a simple, single-layer spiral structure along with its equivalent circuit. The equivalent circuit includes parasitic series resistance and a shunt capacitance. As with the embedded capacitor, the S-parameters found from a 3D HFSS simulation are used in an optimization to find the inductance and the parasitic resistance and capacitance across a desired frequency range. The inductor Q can be calculated from terminated one-port Z_{11} parameter using $Q = \text{mag}[\text{imag}(Z_{11})/\text{real}(Z_{11})]$. An inductor also has a self-resonance that should be investigated so that the inductor is used below this frequency.

Inductance versus the number of turns of the embedded spiral inductor is extracted in the analysis and shown in **Fig. 2(b)**. Ansoft Designer can use this data to obtain required inductance values for embedded inductors. This data, coupled with the parasitic capacitance and resistance values, can be used to construct an inductor library for frequently used values.

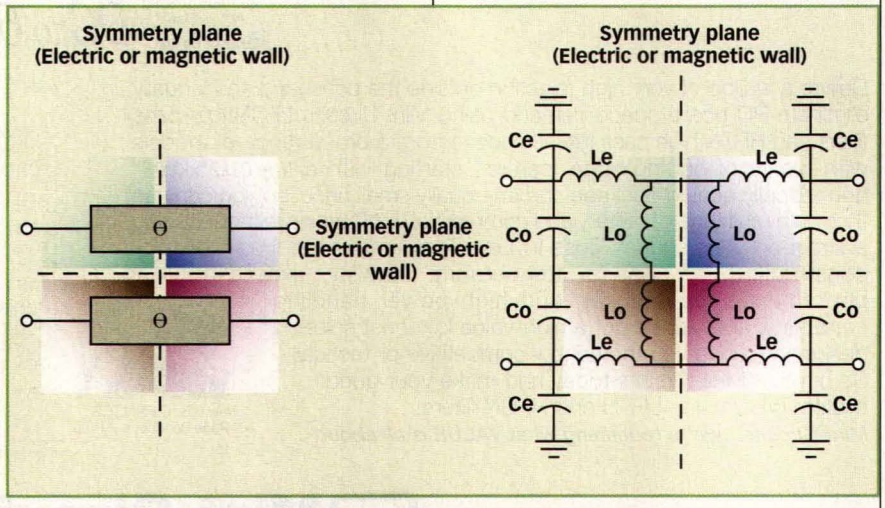
Embedded resistors have significant advantages compared with their chip-resistor counterparts. They are very small, which allows them to be fully integrated within the LTCC module, and have broad applicability since resistance values can be varied from 1 Ω to 1 MΩ. Nevertheless, embedded resistors provide some challenges, such as resistor tolerance and sheet resistivity.

An embedded resistor geometry is a rectangular structure with finite length, width, and height, the equivalent circuit includes parasitic capacitance and inductance. By fitting the S-parameters between the equivalent-circuit model and an HFSS 3D simulation within the proper frequency range, the parallel capacitance value and series inductor parameter values can be found.

The resistance variation of the embedded resistor in terms of the aspect ratio of the film resistor is extracted in the analysis. Since different types of film have independent surface resistance values, the range of resistance that can be obtained varies with the material. A library of resistors can be developed using this information.

Geometric parameterization of planar EM or 3D structures in Ansoft Designer and HFSS, respectively, allow users to develop LTCC design kits based on various embedded LTCC components. Ansoft Designer's Solver On Demand technology permits circuit designers to implement initial LTCC designs using equivalent-circuit models for rapid prototyping followed by more rigorous EM design verification using the synchronized layout information. Circuit/planar EM co-simulation can be performed for individual LTCC components or the entire LTCC design **(Fig. 3)**.

LTCC technology allows lumped elements to be implemented conveniently in a compact size. In this example, a 10-dB directional coupler was designed using LTCC lumped elements rather than coupled lines. The design procedure is based on the classic coupled-line directional coupler, with modifications to allow lumped rather than distributed elements. The derivation provided below shows how to compute lumped element values that provide equivalent coupling to traditional coupled lines. Directional coupler performance of the lumped element equivalent circuit is evaluated using Ansoft Designer's linear analysis. Embedded passive devices with appropriate lumped element values are designed using EM simulation, and comparisons can be made between the circuit simulation and a full 3D geo-



4. Coupled lines equivalent circuit model may be divided using symmetry arguments.

GREAT IDEA ...WHAT'S NEXT?

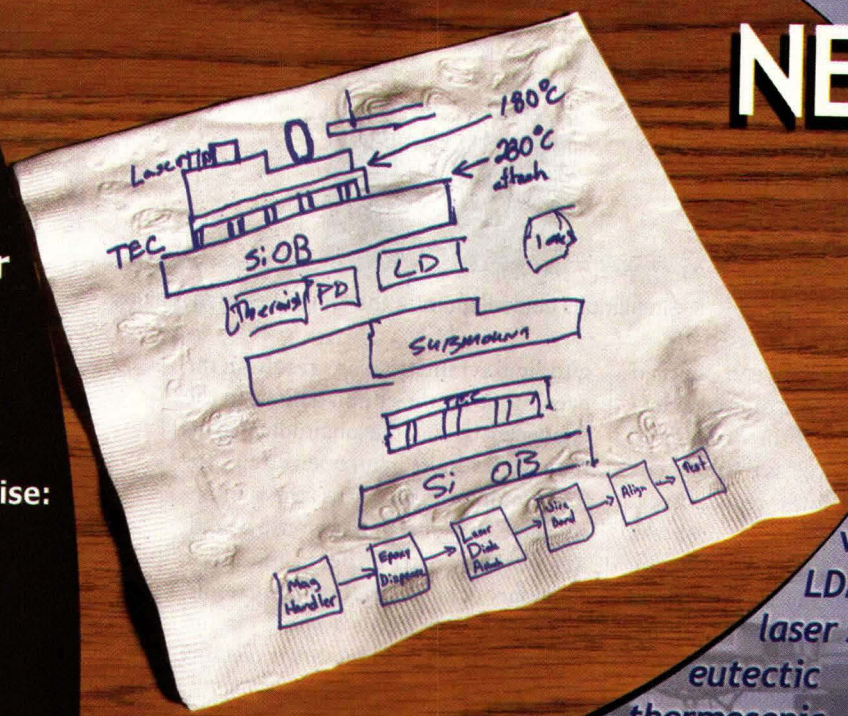


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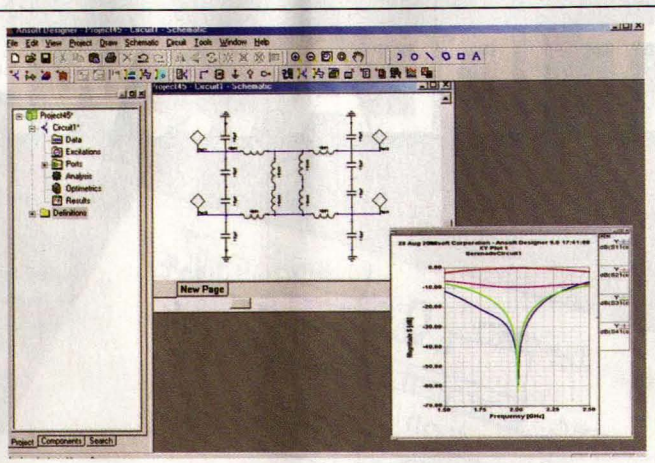
Figure 4 shows a pair of coupled lines with an electrical length of $\theta = 2\pi l/\lambda$ as well as their equivalent circuit. Maximum coupling occurs when $l = \lambda/4$, so coupled-line directional couplers are typically set to this length. A direct equivalent circuit for the structure would include capacitances to ground as well as capacitive coupling between coupled lines. Self-inductance and mutual inductance is used to model the distributed nature of the line as well as the magnetic coupling between lines, respectively. Although it is possible to create a lumped-element implementation with self and mutual inductances, both design and manufacturing would be a fairly difficult. Design of an isolated inductor is fairly straightforward, while designing a pair of inductors with specified self-impedance and mutual impedance is far more complicated. In addition, the mutual impedance requirement might create a sensitive design that would be difficult to manufacture. For these reasons, it is desirable to find an alternative equivalent circuit that has no mutual terms.



5. Simulations helped optimize the lumped element values.

Figure 4 shows that the alternative equivalent circuit does not require a mutual inductance term. This circuit is a modified pi network with the distributed inductance divided into two equal-valued inductors (L_e) and a coupling inductor (L_c) to represent the mutual effect. The challenge is to determine the values of the various capacitors and inductors so that the ideal lumped-element circuit is equivalent to the coupled lines.

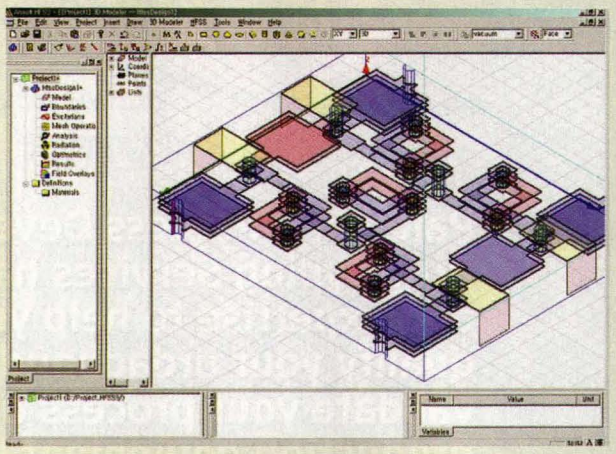
In the equivalent circuit, the two symmetry planes that can be configured as electric or magnetic walls (boundary conditions). Taking the various combinations of electric or magnetic walls will result in four possible combinations that can be used to solve for the four passive component values C_e, L_e, C_o, and L_o.

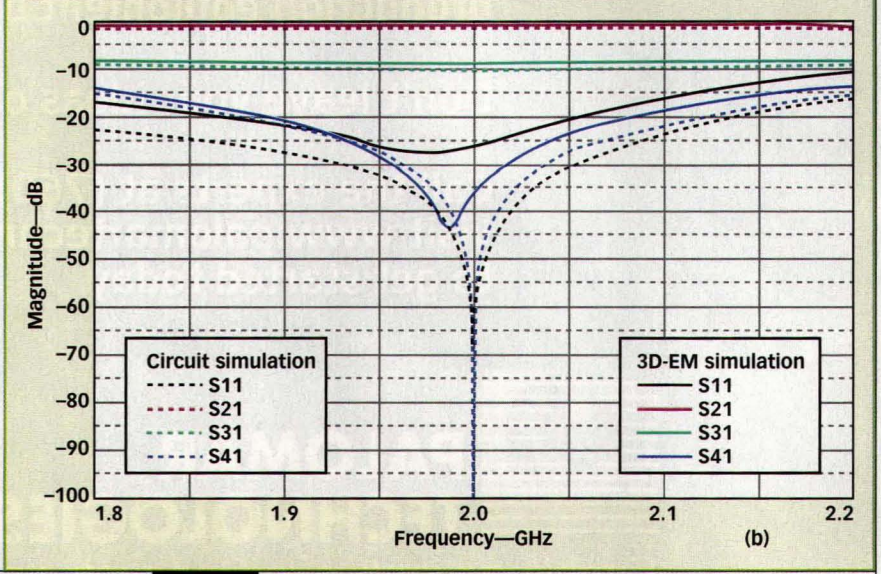
Placing a magnetic wall along the longitudinal symmetry plane results in the even mode on the coupled lines. In the equivalent circuit, the longitudinal magnetic wall results in an open circuit for any conductors that cross the symmetry plane. Toggling the transverse boundary condition to either a magnetic boundary or an electric boundary results in an open circuit or a short circuit, respectively, for conductors traversing the boundary. In each case, the characteristic impedance of the portion of the coupled transmission line is the even impedance Z_{oe} and the electrical length is one-half of the original electrical length. The input impedance looking into the transmission line is given by:

$$Z_{in} = Z_{0e}\frac{Z_L + jZ_{0e}\tan\frac{\theta}{2}}{Z_{0e} + jZ_L\tan\frac{\theta}{2}} \quad (1)$$

For the transverse magnetic wall case, there is an open circuit at the end of the line where $Z_L = \infty$ and Eq. 1 becomes:

(continued on p. 120)





6. LTCC directional coupler was modeled in HFSS (a), and compared with ideal circuit simulation and full 3D geometry in HFSS (b).

(a)

(b)

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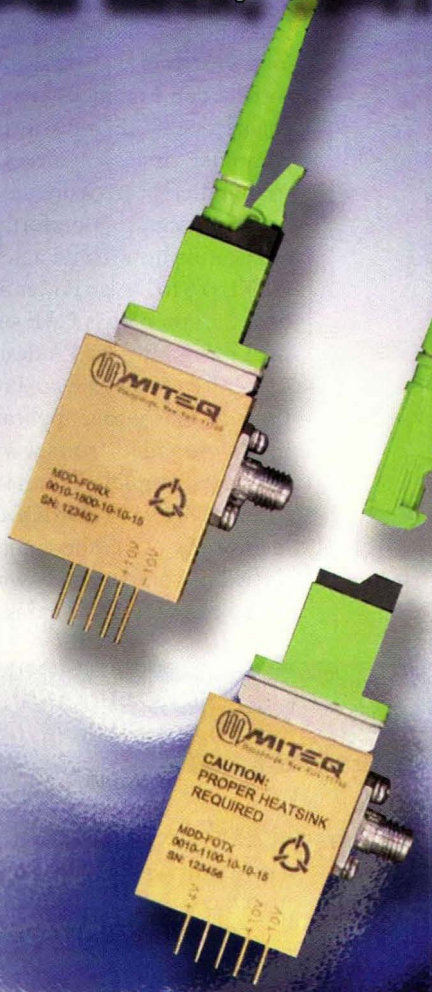
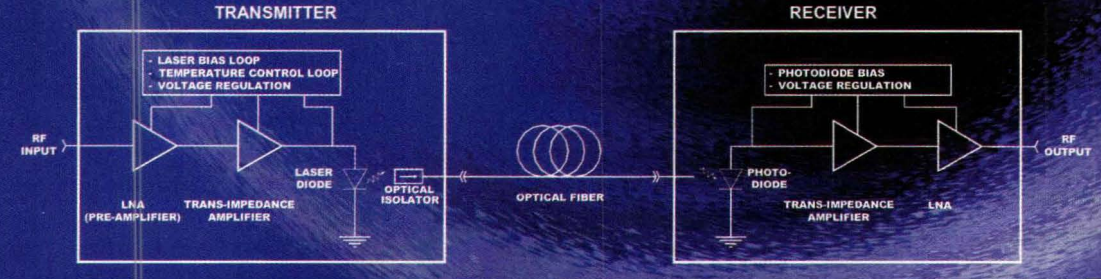


Electrical Specifications
(1 Meter of Fiber)

Model	LBL	SCM	MDD
Frequency (GHz)	.01–3	0.1–6	0.1–11
Gain (dB)	10-20 (17 Typ.)	10-20 (18 Typ.)	10-20 (18 Typ.)
Noise Figure (dB, Max.)	15 (10 Typ.)	20 (14 Typ.)	20 (18 Typ.)
Group Delay (ns ptp, Typ.)	0.1	0.1	0.1
VSWR (In/Out)	2:1	2:1	2:1
Phase Noise (dBc, Typ.)	>100	>100	>100
Input Power @P1dB (dBm, Min.)	-14	-14	-14
Spurious Free Dynamic Range (dB/Hz Min.)	100 (105 Typ.)	101 (103 Typ.)	100 (104 Typ.)



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Software Suite Aids Design Of LDMOS-Based Power Amplifiers

POWER-AMPLIFIER (PA) DESIGN involves tradeoffs among a long list of choices, including desired output power, power supply, efficiency, and linearity, to name a few. In the past, design engineers were required to suffer through a trial-and-error process before developing suitable input, output, and interstage matching networks for a given set of large-signal transistors. Fortunately, with the dramatic improvement in computer-aided-engineering (CAE) software tools for the personal computer, design engineers can execute virtual trial-and-error steps on the computer and more quickly design high-performance amplifiers. An application note from Eagleware Corp., "Using GENESYS to Design Power Amplifiers," describes how the company's CAE software suite can be used to simplify the PA design process.

Written by Eagleware Product Manager Bill Clausen, the six-page application note (which can be downloaded from www.eagleware.com/apps/app_Amplifiers.htm) is based on the use of a model MRF-183 LDMOS device from Motorola (Phoenix, AZ). The stated goal for the amplifier is 24 W output power with 14-dB gain at 800 MHz. The data sheet for this device, which is contained in the GENESYS model library, indicates that it should meet the performance goals for the amplifier.

The application note shows how various features within GENESYS can be used for parameter sweeps of device performance, such as the generation of current-voltage (I-V) curves. Such curves help to identify an optimum bias point (+28 VDC) for the transistor. GENESYS can also be used to extract the large-signal S-parameters for the transistor, by measuring the forward and reverse signal flows through the device at fundamental frequencies of interest.

GENESYS incorporates powerful synthesis modules such as MATCH to speed through the creation of matching structures; the software also provides a wide range of options for generating ploys of simulated performance. Copies of the application note can be downloaded or printed from the company's website.

Eagleware Corp., 635 Pinnacle Court, Norcross, GA 30071; (678) 291-0995, FAX: (678) 291-0971, e-mail: eagleware@eagleware.com, Internet: www.eagleware.com.

With the dramatic improvement in computer-aided-engineering (CAE) software tools, design engineers can execute virtual trial-and-error steps on the computer.

Design System Software Helps Model A 0.5-W, 10-GHz MMIC Amplifier

MONOLITHIC MICROWAVE AMPLIFIERS ARE versatile gain blocks that can be inserted almost anywhere in a circuit where a signal boost is needed (and a bias supply is available). For engineers wanting to learn more about the design of GaAs monlithic-microwave-integrated-circuit (MMIC) amplifiers, an application note from Agilent Technologies, "Using Advanced Design System to Design a MMIC Amplifier," provides a MMIC design flow with specific instructions for creating a 0.5-W, 10-GHz narrowband amplifier on a 100-μm GaAs substrate.

The free application note, publication number 5988-9637EN, can be downloaded from the company's EEsof EDA website at http://literature.agilent.com/litweb/pdf/5988-9637EN.pdf. The massive, 40-page application note does not attempt to describe all of the possible design specifications for a GaAs MMIC amplifier, but it does provide enough specification and design steps to address many common GaAs MMIC amplifier design challenges.

The application note is based on the use of the Advanced Design System (ADS) ADS 2003A suite of CAE software tools as well as example designs and generic component models. As the note points out, the amplifier design process depends on a number of factors, including desired specifications, availability of device models, among others. The note provides a recommended design flow for a two-stage MMIC amplifier with details on how to create input, output, and interstage impedance-matching networks based on ideal components (and then how to replace these components with real-valued components), how to evaluate amplifier gain compression, how to design a branch-line coupler for use at the input and output ports of the MMIC amplifier, how to create the amplifier layout, and how to model transmision-line effects. The note includes an appendix with details on creating new inductor models. Copies of the application note are available for free, from:

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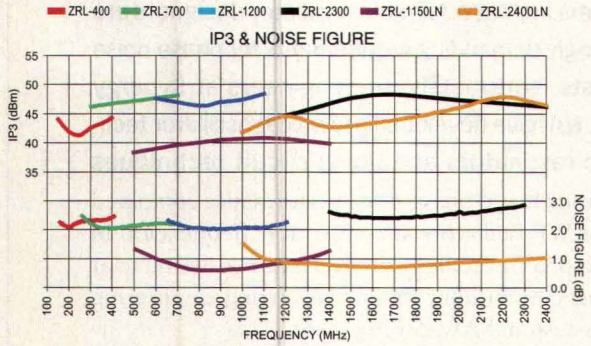

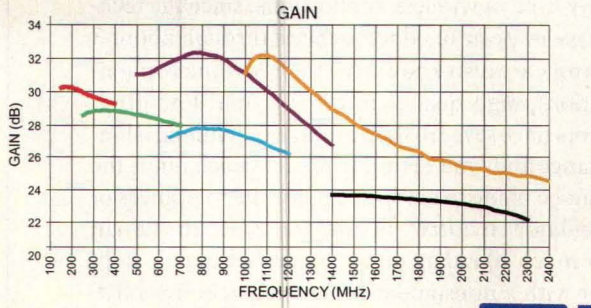

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ZRL-700	250-700	29	2.0	46	24.8	119.95
ZRL-1150LN	500-1400	31	0.8	40	24.0	119.95
ZRL-1200	650-1200	27	2.0	46	24.3	119.95
ZRL-2300	1400-2300	24	2.5	46	24.6	119.95
ZRL-2400LN	1000-2400	27	1.0	45	24.0	139.95

DC Power 12V DC, Current 550mA, Dimensions: (L) 3.75" x (W) 2.00" x (H) 0.80"

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cover story

Ceramic Resonator Oscillators Challenge SAW Performance

The use of ceramic resonators and novel circuit techniques have led to a line of low-cost ceramic resonator oscillators with low phase noise over a wide temperature range.

ULRICH L. ROHDE
Chairman
Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (973) 881-8800, FAX: (973) 881-8361, e-mail: sales@synergymwave.com, Internet: www.synergymwave.com.

Higher-frequency tunable oscillators are vital for wireless systems. As the frequencies of these systems increase, tunable oscillator designers are challenged to meet increasingly demanding requirements for phase-noise performance at lower costs. Fortunately, the engineers at Synergy Microwave Corp. (Paterson, NJ) have developed a low-cost oscillator technology based on ceramic resonators and novel circuit techniques that offers improved thermal-drift and phase-noise performance compared to surface-acoustic-wave (SAW) oscillators at comparable frequencies. In addition, the new ceramic-resonator oscillators (CROs) can be delivered at standard and custom frequencies without the non-recurring-engineering (NRE) costs associated with custom SAW development.

SAW oscillators are widely used in wireless applications, since the technology features very low phase noise at fixed frequencies through about 3 GHz. SAW resonator oscillators are also known for their low microphonic noise (tolerance to vibration), high quality factor (Q), and low jitter. Unfortunately, SAW oscillators have several disadvantages, including a limited operating temperature range and limited tuning range (which limits the amount of correction that can be made to compensate for the tolerances of other components in the oscillator circuitry). In addition, since the design of a new SAW oscillator is much like that of an integrated circuit (IC), development of an oscillator with a nonstandard frequency requires NRE costs on the order of $10,000, in addition to the costs of the oscillators.

Ceramic resonators, which are depicted much like a quartz-crystal res-

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- REDUCE SIZE & COST
- INCREASE PERFORMANCE
- INCREASE POWER HANDLING

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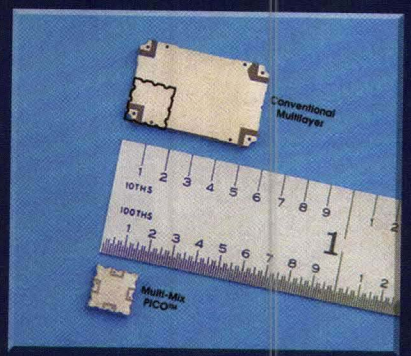

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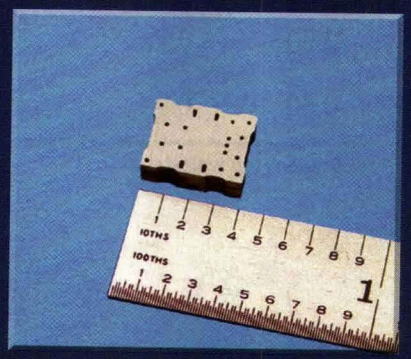

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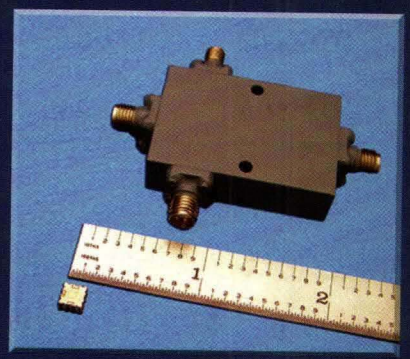

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analog detectors

Model	Freq. Range (GHz)	Input Power Range (dBm) Typ.	Power Flatness (±dB) Typ.	Sensitivity Vout @ Pref (mV) Typ.	Pulse Response (µsec) Typ.	DC Volts (±V)	Sup. Cur. (±mA)
DAC4103	0.01-4.0	-10 to 25	0.60	120	1.5	5	2
DAQ6104	0.1-6.0	-25 to 12	0.75	190	0.3	5	2
DAS8121	0.5-8.0	-30 to 5	0.50	140	0.02	5	9
DAQ10501	0.05-10.0	-30 to 5	0.75	120	1.5	5	2

threshold detectors

Model	Freq. Range (GHz)	Input Power Range (dBm) Typ.	Power Flatness (±dB) Typ.	Histeresis (dB) Typ.	Pulse Response (µsec) Typ.	DC Volts (±V)	Sup. Cur. (±mA)
DTC4001	0.01-4.0	-30 to -5	0.50	0.2	50	5	2.5
DTQ6001	0.1-6.0	-30 to -5	0.50	0.2	50	5	2.5
DTC6002	0.01-6.0	-30 to -5	0.50	0.2	50	5	2.5
DTS6014	0.1-6.0	-12 to 12	0.50	0.3	0.8	5	2

Specifications are typical.

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Comparing CRO and SAW oscillators at 2488.32 MHz

Parameter	SAW-VCO	CRO-VCO
Center frequency	2488.32 MHz	2488.32 MHz (can be set per requirement)
Tuning range	250 PPM	250 PPM
Tuning voltage	1 to 5 V	1 to 5 V
Supply voltage	60 mA at +5 VDC	30 mA at +12 VDC
Output power	+3 dBm	0 dBm (can be set per requirement)
Harmonic rejection	20 dB	20 dB
Typical phase noise		
Offset 10 kHz	–122 dBc/Hz	–123 dBc/Hz
Offset 100 kHz	–142 dBc/Hz	–143 dBc/Hz
Operating temperature range	–20 to +70°C	–40 to +85°C
Thermal drift		
–20 to 70°C	±300 kHz	±400 kHz
–40 to +85°C	N/A	±600 kHz

onator in an equivalent circuit, can achieve the phase-noise performance of a SAW oscillator but over a wider operating-temperature range and at a fraction of the cost. They can be made quite small compared to SAWs, especially at frequencies of 622 MHz and less, and can be readily designed at standard and custom frequencies to about 3 GHz without expensive NRE costs. And they provide sufficient tuning range to compensate for the tolerance variations of circuit elements in the oscillator.

Ceramic resonators are not without flaws, however, since they are susceptible to microphonic noise as well as jitter, and they exhibit low Qs compared to SAW resonators. For the most part, these disadvantages have been overcome by means of a novel oscillator topology (for which a patent has been applied) and integrated control circuitry, using cascaded regenerative filtering of the oscillator active-device emitter and feedback.[1-3] Feedback resistance is incorporated in the topology to reduce thermal drift over a wide temperature range. The patent-pending approach includes a methodology for coupling resonators to enhance the dynamic Q. With a coupled-resonator circuit, the phase-noise performance can be improved and the frequency range can be extended to C- or X-band.

The novel oscillator topology results in CROs capable of operating over a temperature range as wide as –40 to +85°C with minimal frequency drift due to temperature. As an example of the technology, a CRO **(Fig. 1)** was developed for use at 2488.32 MHz. A comparison of the CRO with a SAW oscillator at the same frequency **(see table)** reveals remarkably similar noise performance and tunability. Computer-aided-engineering (CAE) modeling tools used in the development of the 2488.32-MHz

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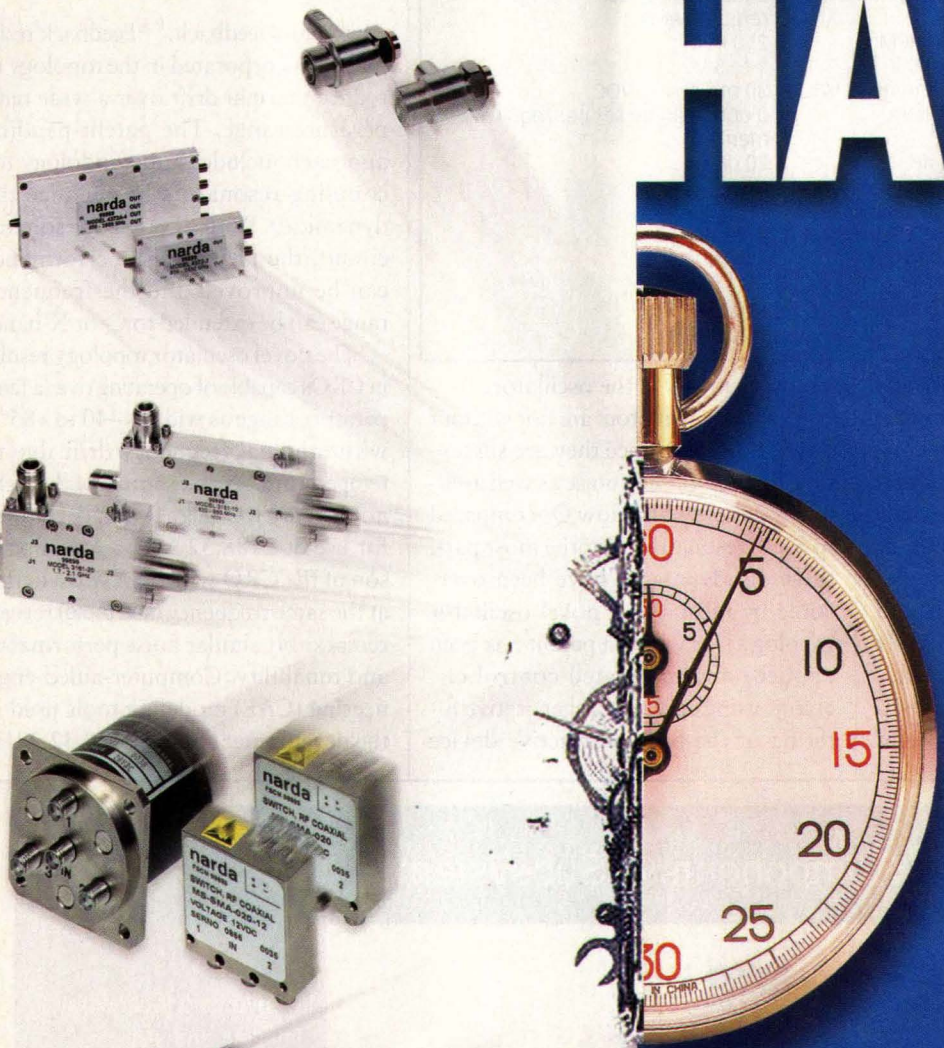

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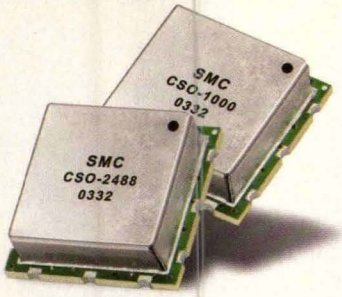
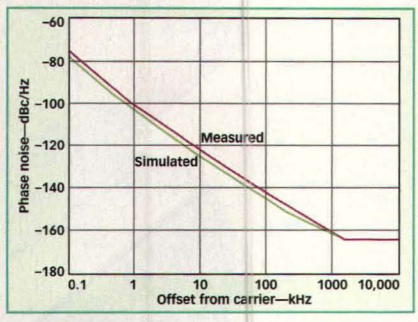
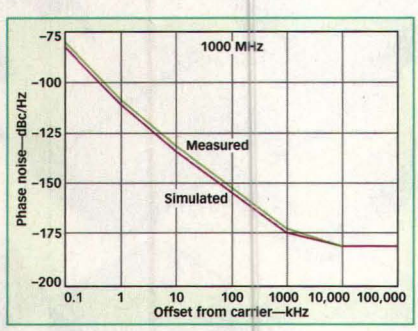


1. This low-cost surface-mount 2488.32-MHz coaxial-resonator oscillator offers low phase noise over a wide temperature range.



2. The measured phase noise of the 2488.32-MHz CRO compares closely with modeled performance.



3. Simulated phase noise of the 1-GHz CRO matches measurement data.

CRO proved to be accurate in predicting expected performance, when compared to measurements **(Fig. 2)**.

The CRO design approach was also used to create a CRO at 1000 MHz. It shares the phase-noise performance (better than –130 dBc/Hz offset 10 kHz from the carrier) of the higher-frequency CRO **(Fig. 3)**, with an operating-temperature range of –40 to +85°C.

The new CRO line is available in standard frequencies, such as 622.08, 1244.16, and 2488.32 MHz, as well as in customer-specified frequencies from UHF through 3 GHz. The oscillators are supplied in surface-mount packages similar to those used for the company's voltage-controlled SAW oscillator (VCXO) line. **Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (973) 881-8800, FAX: (973) 881-8361, Internet: www.synergymwave.com.**

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1. Ulrich L. Rohde and K. Danzeisen, "Feedback Oscillators," Patent No. DE10033741A1 (Germany, Japan, United States).
2. D. Ham and A. Hajimiri, "Concepts and Methods in Optimization of Integrated LC VCOs," *IEEE Journal of Solid-State Circuits*, June 2001.
3. Ulrich L. Rohde, "A Novel RFIC for UHF Oscillators," Invited paper, 2000 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium, Boston, MA, June 11-13, 2000.

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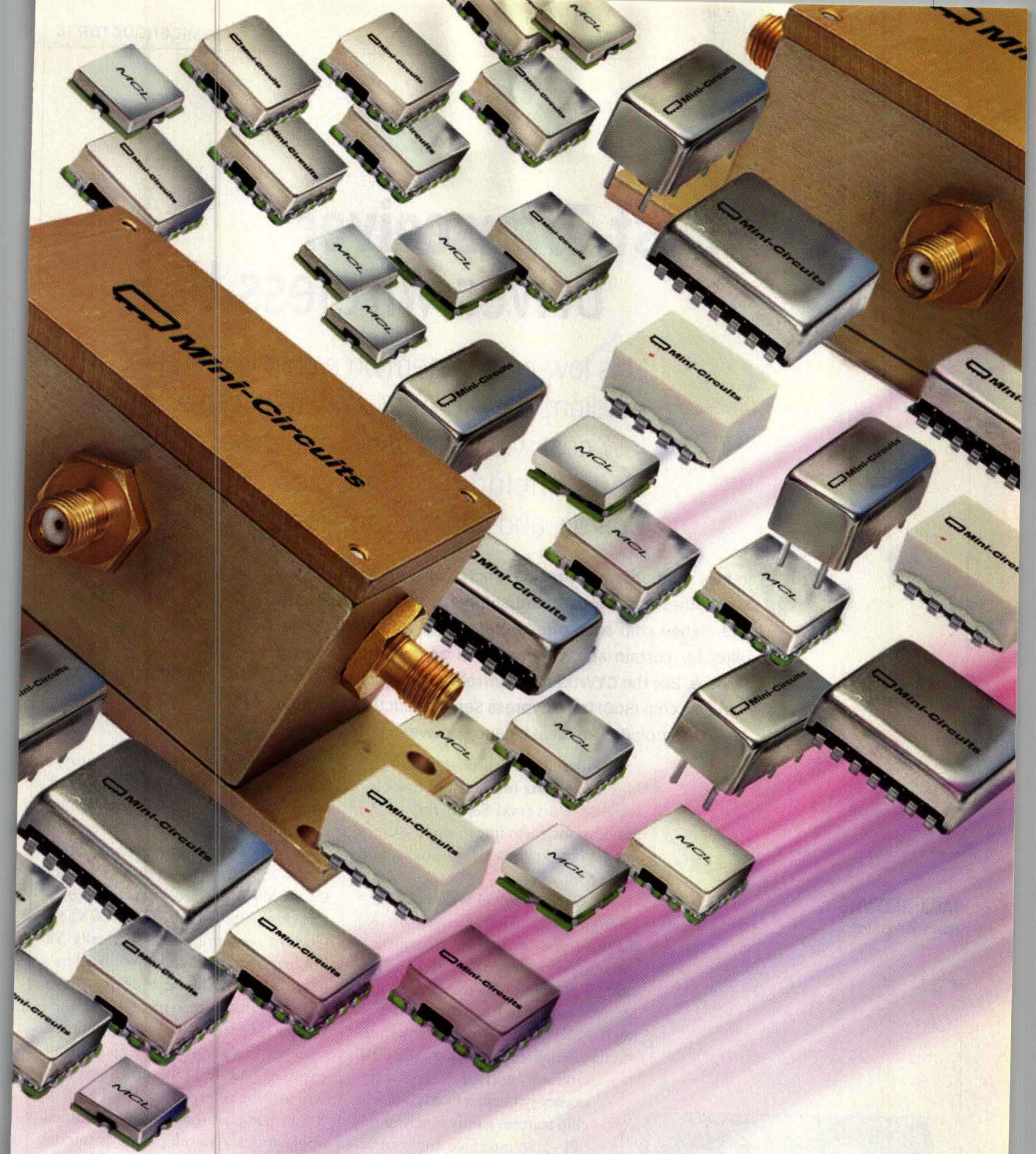

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Low-Cost Transceiver Drives Wireless USB

This low-cost system on a chip is the ideal medium-data-rate 2.4-GHz transceiver for low-cost wireless control and data applications, including computer mice, keyboards, and game controllers.

JACK BROWNE
Publisher/Editor

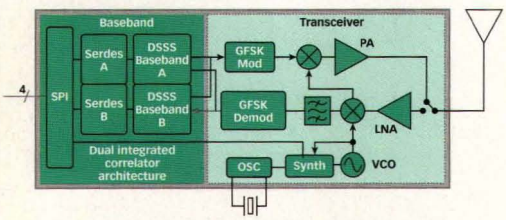
Wireless solutions must provide functionality at minimal cost. Sometimes, standards-based solutions, such as Bluetooth and Zigbee chip sets, offer excessive data-handling capability for certain applications, such as in remote-control devices. But the CYWUSB6934 WirelessUWB™ LS radio system on a chip (SoC) from Cypress Semiconductor Corp. (San Jose, CA) provides an ideal balance between data rate and price, offering data throughput to 62.5 kb/s at 2.4 GHz for a host of low-cost wireless Universal Serial Bus (USB) applications, including in wireless computer mice, keyboards, joysticks, and game controllers.

The CYWUSB6934 WirelessUWB™ LS radio SoC is an integrated circuit (IC) that incorporates dual direct-sequence-spread-spectrum (DSSS) baseband circuits, 2.4-GHz radio transmitter and receiver, Gaussian frequency-shift-keying (GFSK) modulator and demodulator, data serializer/deserializer (SERDES) circuitry, and an on-board frequency synthesizer **(see figure)**. The chip features a fully synchronous SPI slave interface for connection to the central processing unit (CPU) of a target application.

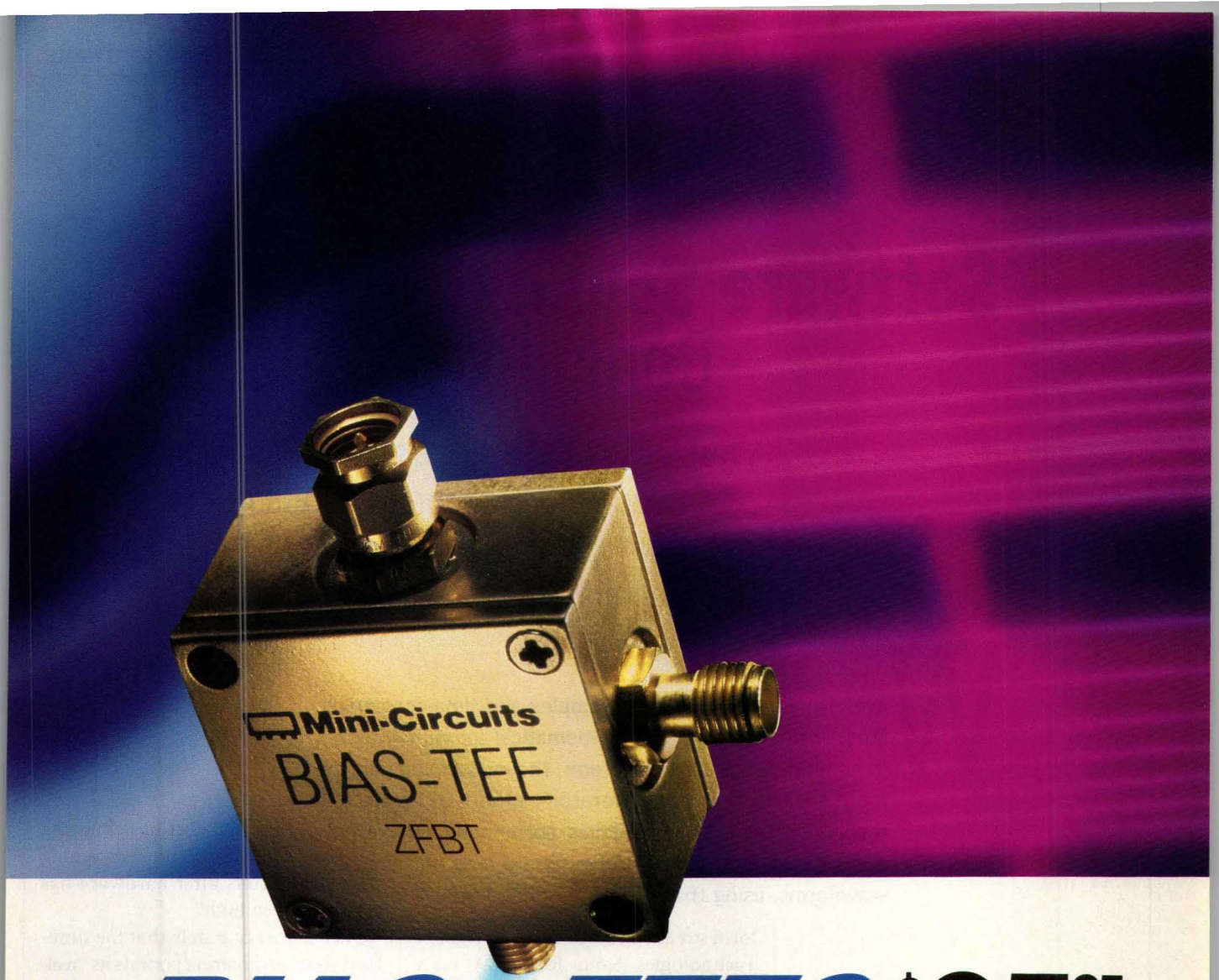
The CYWUSB6934 can connect directly to a USB controller or any standard 8-b microcontroller with an SPI interface. The 2.4-GHz code-division-multiple-access (CDMA) radio transceiver IC employs a reconfigurable baseband section with three operating modes: series, dual-independent, and parallel modes.

The 2.4-GHz transceiver features transmit power of 0 dBm and receiver sensitivity of –90 dBm, which translates into a usable range of better than 10 m. The radio chip is also available as a transmit-only version as model CYWUSB6932. The devices are designed for power supplies of +2.7 to +3.6 VDC. Current consumption is typically 58 mA in receive mode and typically 62 mA in transmit mode; both devices have typical standby current of 1 μA, supporting long battery operating lifetimes.

Both ICs are supplied in 28-lead exposed-paddle SOIC housings, and will also be offered in a 56QFN, 8 × 8-mm package for space-constrained applications. A development kit (model CY3632 WirelessUSB LS), is also complete. P&A: $1.95 (transmit-only model CYWUSB6932), $2.20 [transceiver model CYWUSB6934] (100,000 qty.), and $495.00 (development kit). **Cypress Semiconductor Corp., 3901 North First St., San Jose, CA 95134; (408) 943-2600, FAX: (408) 943-6841, Internet: www.cypress.com.**



Low-cost wireless transceiver model CYWUSB6934 features dual SERDES and DSSS baseband circuitry in addition to a full-featured 2.4-GHz GFSK radio modem.



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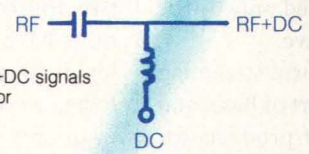

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▲ZFBT-6G	10-6000	0.15	0.6	1.0	32	40	30	1.13:1	79.95
▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.13:1	79.95
▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
★ZNBT-60-1W	2.5-6000	0.2	0.6	1.6	75	45	35	1.35:1	82.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.10:1	35.95
■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	30	35	1.60:1	46.95
•JEBT-4R2G	10-4200	0.15	0.6	0.6	32	40	40	-	39.95
•JEBT-6G	10-6000	0.15	0.7	1.3	32	40	40	-	59.95
•JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
•JEBT-6GW	0.1-6000	0.15	0.7	1.3	25	40	30	-	69.95

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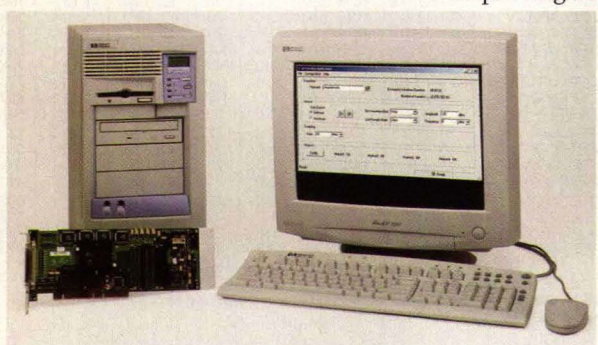
Software Sculpts Complex Waveforms

Working with a vector signal generator, this advanced software can generate complex waveforms of virtually any size for stimulating wireless, radar, and EW systems.

JACK BROWNE
Publisher/Editor

Waveform generation can be complex and time-consuming. Most engineers resort to a mathematical software program to generate a complex waveform. They must then port the math files to a signal generator capable of accurately responding to the translated files. Fortunately, there is now a simpler way to create and generate long and complex waveforms, using the N5110A Baseband Studio for Waveform streaming software from Agilent Technologies (Santa Rosa, CA) on a personal computer (PC) along with one of the company's model E4438C ESG or E8267C PSG vector signal generators. The software supports virtually any waveform file size, limited only by the size of the PC's hard drive.

The N5110A waveform streaming solution **(see figure)** is part of Baseband Studio, a new family of products for improving the efficiency of the baseband design process when creating wireless and military products. Design verification at baseband has become increasingly important as a greater portion of the intelligence in wireless systems resides at the baseband level. By verifying the performance of baseband components and algorithms at early stages of design, engineers can save the time and cost of debugging algorithms and redesigning circuits after hardware has been built.



The N5110A Baseband Studio for Waveform Streaming software from Agilent Technologies supports virtually any waveform size, limited only by the size of the PC's hard drive.

The more accurately that the simulated signal environment portrays its "real-world" counterpart, the more likely the system will perform well in the field. For example, receivers sent into service after being subjected to conservative approximations of signal conditions have the potential to fail when highly stressed, resulting in system performance degradation and reduction in quality of service. In the wireless industry, the downtime this could create would be unacceptable. A similar situation exists for radar and EW systems, both of which are expected to perform under varying propagation conditions as well threat scenarios. Once again, the likelihood of acceptable performance depends in large measure on how well the stimulus signals reflect these conditions.

In many cases, this level of verification can only be obtained with signal scenarios that range in length from a few minutes to several hours. In wireless applications, this is because complicated processes such as paging, acqui-

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sition, and channel assignment include large amounts of non-repetitive data. In radar applications, designers often capture live signals off the air over long periods to use as a stimulus. In both cases, the files containing these signals are invariably larger than any baseband generator can store in memory, so engineers are faced with two basic choices: They can partition the signal stream into segments small enough to fit in this memory and play back the entire file segment by segment. They can also build their own system to store, play back, and upconvert their waveforms. Both of these solutions are time-consuming, and creating a "homebrew" solution can be costly.

Agilent's N5110A Baseband Studio for Waveform Streaming software eliminates the need to resort to either of these processes by allowing the entire signal, regardless of length, to be stored on a PC hard drive and streamed out continuously through a PC-resident Baseband Studio PCI card (Agilent's N5101A) at high data rates to an ESG or PSG vector signal generator equipped with a baseband generator. (The company's E4438C series of vector signal generators includes models operating from 250 kHz to 1, 2, 3, 4, and 6 GHz, while the model E8267C microwave vector signal generator operates from 250 kHz to 20 GHz.) The instrument then converts the waveform into analog in-phase/quadrature (I/Q) or RF signals that are output as a stimulus signal to the device under test. The data rate of the streaming signal can be as high as 40 MSamples/s, which translates into a 16-MHz bandwidth for each of the I and Q channels and a total RF modulation bandwidth of 32 MHz. The bandwidth is sufficient to allow simulation of multiple modulated communications channels or generation of pulsed waveforms.

The N5101A PCI card is an essential element of the solution, because it performs operations on the baseband signals and controls I/O functions. It employs an advanced field-programmable gate array (FPGA) from Xilinx (San Jose, CA, www.xilinx.com), which enables the card to be reprogrammed to accommodate the signals that are processed by the streaming software. As many as four markers are available for creating output signals synchronized with the waveform, and waveform control functions while streaming include start/stop, looping, and an application programming interface (API) for developing custom levels of automation. P&A: $15,000 to $65,000 (N5110A Baseband Studio for Waveform Streaming software) and $4,500 (N5101A PCI card); stock. **Agilent Technologies, Test and Measurement Organization, 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052; www.agilent.com/find/basebandstudio.**

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MCA1-42	7	1000-4200	6.1	35	6.95
MCA1-60	7	1600-6000	6.2	30	7.95
MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
MCA1-60LH	10	1700-6000	6.3	30	8.45
MCA1-24MH	13	300-2400	6.1	40	6.95
MCA1-42MH	13	1000-4200	6.2	35	7.95
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High-throughput measurements, such as antenna testing and RF integrated-circuit (RF IC) characterization, call for a fast-switching frequency synthesizer. Until recently, instrument synthesizers with microsecond switching speed came with hefty price tags. But the new 2400 Series of microwave frequency synthesizers from Giga-tronics (San Ramon, CA) offer fast frequency switching and low phase noise without breaking the bank. Several instrument configurations are available covering 10 MHz to 8 GHz, 10 MHz to 20 GHz, and 10 MHz to 40 GHz.

The 2400 Series of frequency synthesizers **(see figure)** includes models with and without front-panel display screens and keypads. Model 2408L, for example, operates from 10 MHz to 8 GHz, while models 2420L and 2440L operate from 10 MHz to 20 GHz and 10 MHz to 40 GHz, respectively. The same numbers with "AL" suffix (for example, model 2408AL) are configured with a blank front panel, rear-panel RF output jack, GPIB interface, and optimized for automatic-test-equipment (ATE) environments.

Standard models offer 1-kHz frequency resolution; an option shaves tuning resolution to a fine 0.1 Hz. The synthesizers feature generous output power, with +15 dBm output power to 20 GHz and +9 dBm output power to 40 GHz. At an output level of +10 dBm, the output power remains flat within ±1.0 dB to 20 GHz and ±1.2 dB to 40 GHz.

Although the frequency synthesizers can be programmed to sweep through frequencies and power levels is about 10 ms per point, it is in List mode that they show their true speed. By downloading a list of frequencies and power levels via GPIB or with an RS-232C or USB connection to a personal computer (PC) running the supplied WaveMaker software, the 2400 Series synthesizers can settle to a new frequency in less than 400 µs and settle to a new power level is less than 200 µs. The Windows-based WaveMaker software includes an autoprogramming mode and includes a command-line interpreter.

The synthesizers maintain spectrally pure output signals, with phase noise of –91 dBc/Hz offset 100 Hz from a 2-GHz carrier and –117 dBc/Hz offset 100 kHz from a 2-GHz carrier. At 10 GHz, the phase noise is –79 dBc/Hz offset 100 Hz and –105 dBc/Hz offset 100 kHz. P&A: $17,000 and up; 6 wks. **Giga-tronics, Inc., 4650 Norris Canyon Rd., San Ramon, CA 94583; (925) 328-4650, FAX: (925) 328-4700, e-mail: sales@gigatronics.com, Internet: www.gigatronics.com.**

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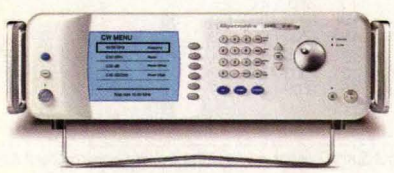

The 2400 Series of frequency synthesizers combine fast switching speeds and excellent spectral purity at output frequencies from 10 MHz to 40 GHz.

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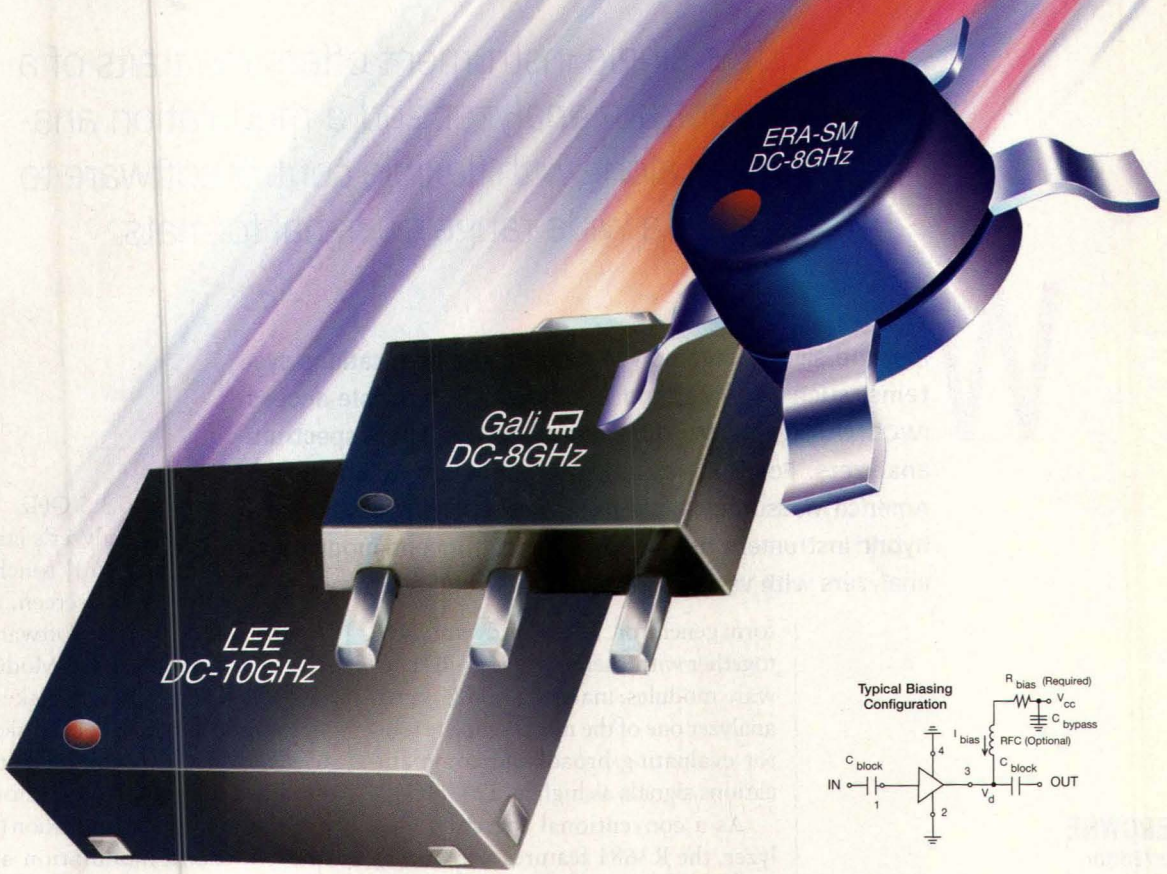

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Analyzer Captures Broadband Signals

This single instrument offers the traits of a spectrum analyzer and a modulation analyzer along with flexible control software to cover a wide range of signal formats.

Wideband signals common to modern communications systems, such as wideband code-division-multiple-access (WCDMA) signals, tax the limits of even the best spectrum analyzers. For that reason, the engineers at Advantest America Measuring Solutions (Edison, NJ) have developed a hybrid instrument that combines spectrum and modulation analyzers with vector signal generator and arbitrary waveform generator. These hardware tools, together with a series of "plug-in" software modules, make the R3681 signal analyzer one of the most complete tools for evaluating broadband communications signals as high as 32 GHz.

JACK BROWNE
Publisher/Editor

As a conventional spectrum analyzer, the R3681 features a frequency range of 20 Hz to 32 GHz. Resolution bandwidths can be set from 1 Hz to 10 MHz. As a modulation analyzer, the R3681 has a frequency range of 20 Hz to 6 GHz. The general level accuracy is better than ±0.73 dB from 50 MHz to 2.5 GHz with 10 dB attenuation and 100-kHz resolution bandwidth.

The R3681 exhibits excellent spectral purity, with phase noise of –120 dBc/Hz offset 10 kHz from the carrier and –155 dBc/Hz offset 10 MHz from the carrier. The average displayed noise level is –158 dBm at 1 GHz. At the other end of the dynamic range, the analyzer offers a typical 1-dB compression point of +10 dBm from 200 MHz to 3.5 GHz and a third-order intercept point of typically +26 dBm from 2 to 3.5 GHz.

The analyzer's large [12-in. (30.5-cm)] touch-sensitive display screen, flexible controls, and modular software make it easy to use. Its Wizard Module Test (WMT) system platform makes it possible to add and replace extension modules for different requirements, with modules for signal generation (SG), arbitrary waveform generation (AWG), and wideband modulation analysis (WBA). The analyzer features an adjacent-channel-leakage-power (ACLP) level of –84 dBc for one-carrier measurements with a 5-MHz offset and ACLR level of –77 dBc for four-carrier measurements with a 5-MHz offset.

The R3681 can be equipped with an option (68) for performing offset frequency-division multiplex (OFDM) modulation analysis for IEEE 802.11a WLANs, which supports automatic detection of BPSK, QPSK, 16QAM, and 64QAM modulation formats. P&A: $68,900 (R3681) and $9900 (OFDM option); 6 wks. **Advantest America Measuring Solutions, Inc., 258 Fernwood Ave., Edison, NJ 08837; (732) 346-2600, FAX: (732) 346-2610, Internet: www.Advantest.com/instruments.**

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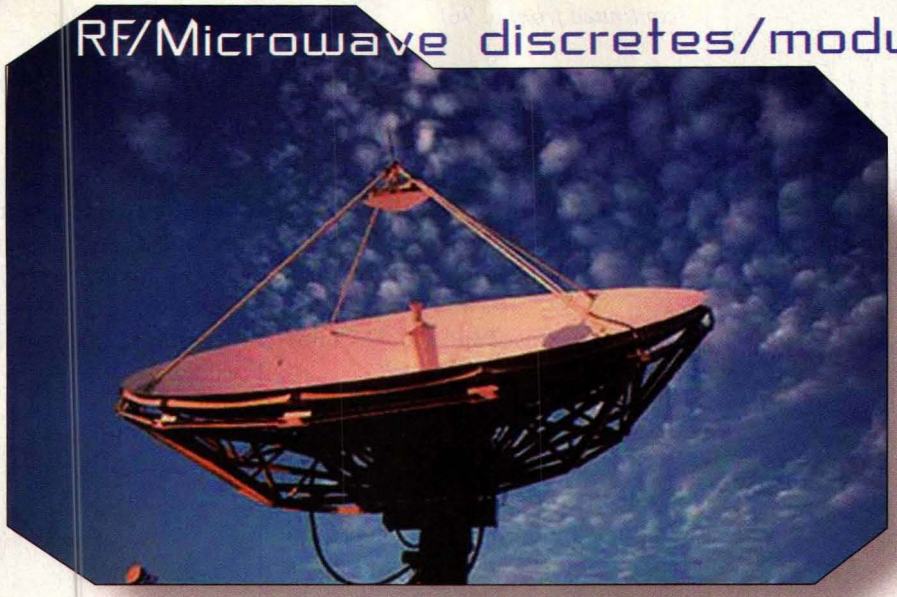

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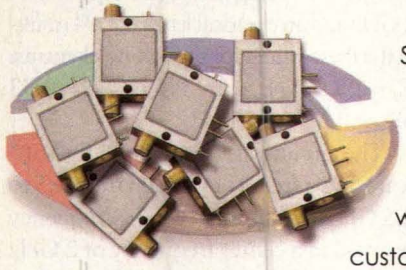

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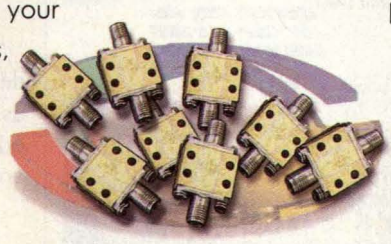

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(continued from p. 96)

$$Z_{in} = jZ_{0e} \cot\frac{\theta}{2} \qquad (2)$$

The input impedance looking into the equivalent circuit is simply the impedance of the capacitor C_e given by:

$$Z_{in} = \frac{1}{j\omega C_e} \qquad (3)$$

Equating Eqs. 2 and 3 makes it possible to solve for C_e:

$$C_e = \frac{1}{\omega Z_{0e}} \tan\frac{\theta}{2} \qquad (4)$$

For the case of an electric wall in the transverse direction, input impedance looking into the transmission line is given by Eq. 1. This time, however, there is a short circuit at the end of the transmission line, so $Z_L = 0$ and Eq. 1 becomes:

$$Z_{in} = jZ_{0e} \tan\frac{\theta}{2} \qquad (5)$$

It is easier to utilize the admittance when equating to the equivalent circuit because the equivalent circuit is the parallel combination of an inductor and a capacitor. The corresponding input admittance is:

$$Y_{in} = -jY_{0e} \cot\frac{\theta}{2} \qquad (6)$$

The input admittance looking into the equivalent circuit is given by:

$$Y_{in} = \frac{1}{j\omega L_e} + j\omega C_e \qquad (7)$$

Equating Eqs. 6 and 7 with the use of Eq. 4 helps solve for L_e:

$$L_e = \frac{Z_{0e}}{2\omega} \sin\theta \qquad (8)$$

This same procedure can be used to derive the odd-mode impedance Z_{oo} using a longitudinal electric wall. The odd mode inductance and capacitance are given by:

$$C_o = -\frac{Y_{0o}}{\omega} \cot\frac{\theta}{2} + \frac{1}{\omega^2 L_e} - C_e \qquad (9)$$

$$L_o = \frac{1}{\omega^2 (C_e + C_o) - \omega Y_{0o} \tan\frac{\theta}{2}} - L_e \qquad (10)$$

and

SEE EQ. 10 BELOW AT LEFT

The final step for designing a lumped-element directional coupler is to provide a method for determining the required Z_{oe} and Z_{oo} to plug in to the equations for the even and odd inductances and capacitances. These parameters are determined from the desired coupling value.[1]:

$$C_{dB} = -10 \log_{10}\frac{1}{C^2} dB \qquad (11)$$

$$Z_{0e} = Z_0\sqrt{\frac{1+C}{1-C}} \qquad (12)$$

$$Z_{0o} = Z_0\sqrt{\frac{1-C}{1+C}} \qquad (13)$$

Parameter Z_o can be chosen based on design requirements. Coupling coefficient C_{db} for this design is 10 dB. Equations 11, 12, and 13, along with Eqs. 4, 8, 9, and 10, form the basis for the design. Choosing a center frequency of 2 GHz and an electrical length of λ/4 results in the these values for the passive elements: C_e = 2.21 pF; L_e = 1.43 nH; $C_o/2$ = 0.53 pF; and L_o = 1.55 nH.

The circuit was entered into the software and a frequency sweep from 1.5 to 2.5 GHz was simulated. The frequency resulted in a center frequency of 2 GHz and a coupling value of 10 dB.

Now the lumped elements can be incorporated in an LTCC substrate. Capacitors can be implemented with a simple parallel plate structure, and inductors can be implemented using a helical structure with vias traversing from layer to layer. Simulations helped to optimize the lumped element values **(Fig. 5)**.

The results of the directional coupler modeled in HFSS **(Fig. 6a)** compared to the results of the ideal circuit simulation **(Fig. 6b)** clearly show that 10-dB coupling was achieved, and that the derivation of the equivalent circuit model is a viable approach to LTCC design. MRF

REFERENCE

1. S.B. Cohn, "Shielded coupled-strip transmission lines," IRE Trans., PGMTT-3, Oct. 1955, pp. 29-38.

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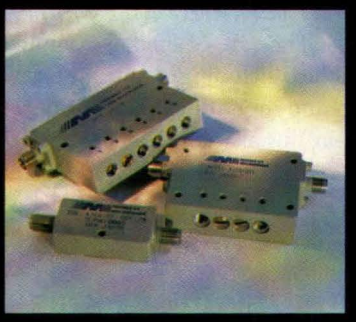

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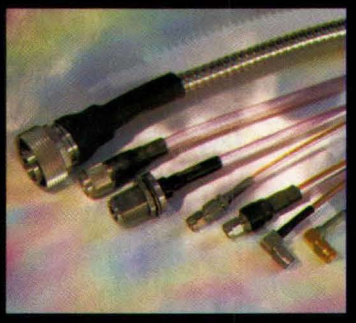

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D.C. - 40 GHz

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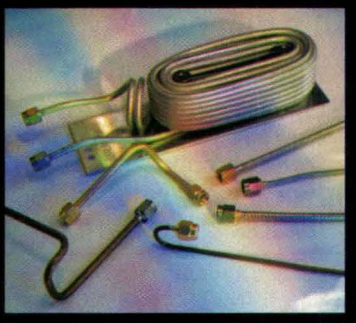

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Delay Lines, D.C. - 40 GHz

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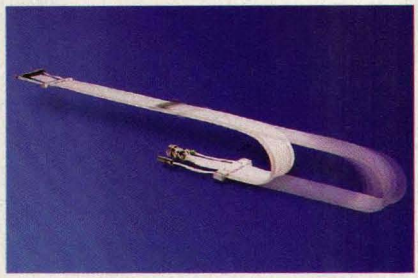

The cables function in a controlled motion without a cable track or energy chain for stroke lengths up to 60 in. (1.5 m) and acceleration up to 4 G (40 m/sec^2). They are offered as complete assemblies, including connector termination and mounting clamps for easy "drop-in" installation. The cable assemblies can operate at the same small bend radii as traditional high-flex planar cables. They also have surpassed flex-life testing of more than 20 million cycles to date.

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12dB	DBTC-12-4	5-1000	0.7	21
13dB	DBTC-13-4	5-1000	0.7	18
13dB	DBTC-13-5-75	5-1000	1.0	19
		1000-1500	1.4	17
16dB	DBTC-16-5-75	5-1000	1.0	21
		1000-1500	1.3	19
17dB	DBTC-17-5	50-1000	0.9	20
		1000-1500	1.0	20
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S		
Satellink	www.satellink.com	126
Saw Electronic Solutions	www.on.wplus.net/aec/; e-mail: ses4@attbi.com	126
Sawtek, a Triquint Company Inc	www.triquint.com; e-mail: info-mmw@tqs.com	91
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Sector Microwaves Ind Inc	www.sectormicrowve.com; e-mail: sales@sectormicrowave.com	126
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Signal Technology	www.sigtech.com	82
Stratedge	www.stratedge.com/mwrf	45
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Synergy Microwave	www.synergymwave.com; e-mail: sales@synergymwave.com	59
Synergy Microwave	www.synergymwave.com; e-mail: sales@synergymwave.com	87
T		
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T&C Power Conversion,inc.	www.tcpowerconversion.com	124
TTE Incorporated	www.tte.com	13
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Voltronics International Corp	e-mail: info@voltronicscorp.com	79
W		
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Z		
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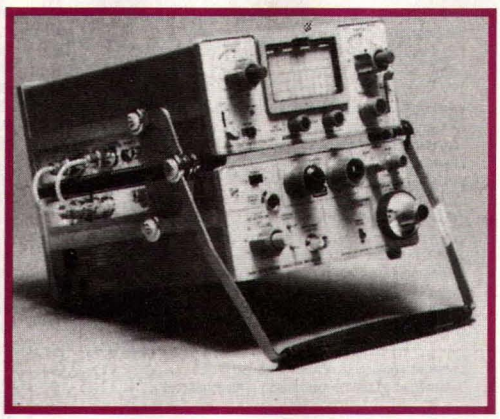

MORE THAN 33 YEARS AGO, Tektronix (Beaverton, OR) launched its 500-MHz model 1401 spectrum-analyzer module for just under $2000. Designed for use with a compatible oscilloscope, the portable analyzer module featured a 60-dB dynamic range.

next month

Microwaves & RF October Editorial Preview
Issue Theme: Frequency Synthesis

News
Techniques for generating high-frequency signals have evolved rapidly during the last decade, with traditional analog techniques such as phase-locked loops (PLLs) now often sharing space with newer direct-digital-synthesizer (DDS) circuits on integrated frequency-generation modules. To commemorate this Frequency Synthesis issue theme, this Special News Report will survey some of the current suppliers of RF and microwave frequency synthesizers and examine some of the differences in the technologies used in these modules, including direct and indirect synthesis, fractional-N synthesis, PLL synthesis, and DDS technology. .

Design Features
In keeping with October's frequency-synthesis theme, the lead technology article will explore the design of compact, programmable single-loop frequency synthesizers capable of fast switching speed as well as relatively low phase noise. In other articles, a well-known modulation expert offers an update on minimum-sideband (MSB) ultra-narrowband modulation techniques. Authors from Linear Technology describe a line of active mixers capable of achieving high linearity, while a contributor from Agilent Technologies describes proven methods for making pulsed S-parameter measurements

Product Technology
October offers a first look at several new RF ICs for wireless infrastructure and fixed-wireless communications systems, including a pair of modulator ICs. Additional product stories feature a hands-on review of a trio of instructional CD-ROM courses, a report on a novel room-temperature process for improving the performance of wafers for SAW devices, a low-cost single-chip 802.11b WLAN transceiver IC with integrated power amplifier and transmit/receive (T/R) switch, and the key features of a new line of affordable digital oscilloscopes with massive signal-processing power.

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DC-100	30	±0.5	0682-30F
DC-250	10	±0.5	0682-10F
Uncalibrated models			
DC-60	40	±1.0	0682-40
DC-100	20	±0.6	0682-20
DC-100	30	±0.5	0682-30
DC-200	30	±2.0	0682-30A
DC-250	15	±1.2	0682-15
DC-500	10	±0.25	0682-10

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